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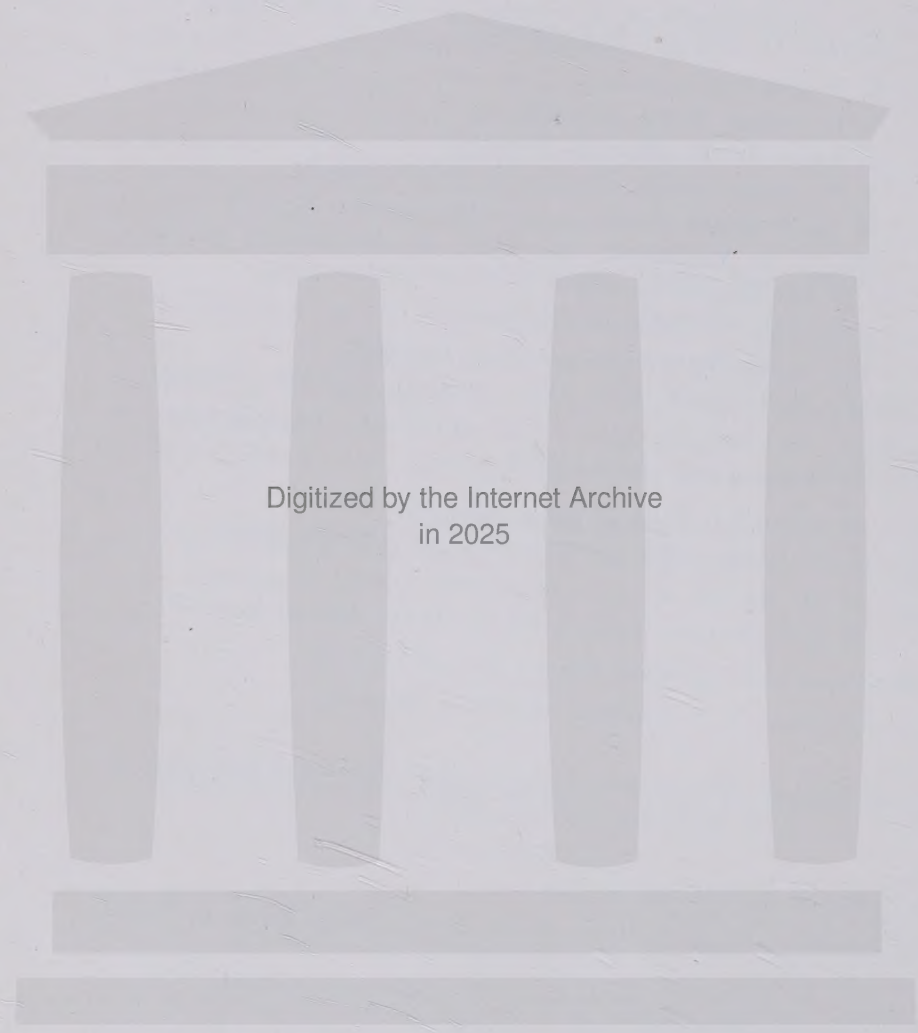

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PART I.

POMOLOGY.

EXPERIMENTS WITH DOUBLE-WORKED PEARS ON QUINCE STOCKS.

By N. H. GRUBB.

It has been known for many years that certain varieties of pear, when budded or grafted direct on quince stocks, do not make satisfactory trees; either the growth of most or all of the trees is stunted, and the trees are apt to die while quite young, or the trees, after growing well for several years, are apt to snap off at the union between stock and scion. The usual practice has been to "double work" these varieties of pear. A variety known to do well when worked direct on quince is used as an "intermediate"; i.e., this variety is first worked on the quince stock, and the other variety, which will not "do" if worked on quince direct, is then worked on this. Experiments along these lines have been under way at East Malling since 1920; they have now reached a stage at which they afford some guidance to nurserymen and growers.

When the work was started, though there was no difficulty in making a list of varieties said to require double working, it was by no means easy to get any definite information regarding the best "intermediates" to use. Several nurserymen kindly told us what varieties they were using as intermediates; these we decided to test in our experiments, and we added one or two more which we guessed would prove to be either specially suitable or specially unsuitable.

The final list of varieties used as intermediates was as follows:—

Vigorous: Pitmaston Duchess, Vicar of Winkfield, Beurré d'Amanlis, Catillac, Charles Ernest, Bellissime d'Hiver, Fertility.

Moderate Vigour: Conference, Hessle, Josephine de Malines.

Rather Weak: Beurré Capiaumont, Chaumontel, Dr. Jules Guyot, Orange Bergamotte, Winter Nelis.

The only varieties in this list which could be said to be quick cropping are Conference, Dr. Jules Guyot and Fertility.

Of the varieties commonly "double worked" by nurserymen a small selection was made, and one or two sometimes "single worked" were added by way of comparison. The final list was as follows:

Beurré Bosc, Beurré Clairgeau, Dr. Jules Guyot, Marie Louise, Souvenir du Congrès. (The trees of Beurré Bosc are still too small to give definite indications.)

Thus one variety, Dr. Jules Guyot, was used both as "intermediate" and as "second scion." Single worked trees of all these "second scion" varieties, except Beurré Bosc, were also planted for comparison. All the trees were worked (or double worked) on Angers Quince (Type A).

None of the trees have yet borne more than an occasional fruit. A good many of the trees of Souvenir du Congrès, however, blossomed more or less in 1925, and freely in 1926, whilst in the latter year there has been enough blossom on the trees of Beurré Clairgeau and some of those of Dr. Jules Guyot to indicate certain tendencies.

The records here discussed, therefore, deal mainly with the vigour of growth of the trees, as shown by length of wood growth each year, the girth of the stem and the weight of prunings cut away ; with such notes on the amount of blossom as are available.

It may be said at the outset that the experiments have already demonstrated the need for double working both Beurré Clairgeau and Souvenir du Congrès. Of the latter variety two series of trees have been planted. The earlier series planted in the winter of 1921-22 included trees on three intermediates, with eight trees worked direct on quince. Of these eight trees, two died in the summer of 1925, and only one* of the other six approaches any of the double worked trees in vigour. In the second series, planted in 1922-23, trees on four intermediates, with four single worked trees, have so far given a similar result, though all the single worked trees are still alive.

A series of trees of Beurré Clairgeau, planted in 1922-23, included four single worked trees. These have produced, on the average, less than half as much length of wood growth as the weakest batch of double worked trees, and only one-fifth as much as the strongest.

With Dr. Jules Guyot and Marie Louise the failure of the single worked trees is less striking. Of Marie Louise the only trees available for comparison are four single worked trees, and four trees on each of three intermediates. Here the four single worked trees, as shown by both length of wood growth and girth of stem, are considerably more vigorous than the four trees double worked on Catillac, about equal to the four trees on Dr. Jules, and considerably weaker than the four trees on Charles Ernest. Since both Catillac and Dr. Jules are themselves none too satisfactory when single worked, the comparison does not indicate that the single worked trees of Marie Louise will prove satisfactory, even though they have grown moderately well so far.

Of Dr. Jules Guyot four single worked trees are available for comparison with eight or ten trees on each of five intermediates, and with five trees on another. The single worked trees are the least vigorous ; but they are only slightly less vigorous than those double worked on Catillac, and none of them as yet seem likely to die. All those on other intermediates are much more vigorous.

Wherever the single worked trees have been strikingly dwarfed as compared with those double worked, there has been a big increase in the number of fruit

* Since the above was written this tree has snapped off at the union.

buds they have produced in proportion to the size of the tree. This, presumably, is only to be expected.

The effect on the vigour of the trees of the different varieties used as intermediates is very strikingly different. It is seen most clearly up to the present where the second scion is either Beurré Clairgeau or Souvenir du Congrès. Thus the trees of Beurré Clairgeau on Bellissime d'Hiver and Vicar of Winkfield are exceptionally strong ; those on Conference, Catillac and Josephine de Malines are moderate in growth, whilst those on Dr. Jules Guyot are distinctly dwarfed, having produced much less than half as much length of wood growth as those on Bellissime d'Hiver. When examined statistically, the more striking of these differences prove to be significant on our usual reckoning, i.e., there being more than thirty chances to one that the result would show the same tendency on repetition of the experiment.

Similarly, the trees of Souvenir du Congrès planted in 1921-22 are strongest on Winter Nelis and Beurré d'Amanlis, and of moderate vigour on Conference. Those planted in 1922-23 are strongest on Fertility, Pitmaston Duchess and Beurré d'Amanlis (in that order), and much dwarfed on Orange Bergamotte, the length of wood growth on the latter being less than one-third that on Fertility. Here again the larger differences are statistically significant ; even that between Congrès on Fertility and on Pitmaston gives more than 100 chances to one in favour of a similar result on repetition of the experiment.

The trees of Dr. Jules Guyot are strongest on Vicar of Winkfield, moderate in vigour on Beurré d'Amanlis, Beurré Capiaumont and Bellissime d'Hiver, and distinctly dwarfed on Catillac.

These results are shown in tabular form below.

Effect of various Intermediates on vigour of Second Scion.

Intermediate.	Second Scion. Souvenir du Congrès.	Beurré Clairgeau.	Dr. Jules.	Marie Louise.
Pitmaston	strong	—	—	(strong)
Vicar of Winkfield	—	strong	strong	—
Beurré d'Amanlis	fairly strong	—	fairly strong	(fairly strong)
Catillac	—	moderate	weak	weak
Charles Ernest	—	—	—	strong
Bellissime d'Hiver	—	very strong	fairly strong	—
Fertility	very strong	—	—	(fairly strong)
Conference	moderate	moderate	—	—
Jos. de Malines	—	moderate	—	—
Beurré Capiaumont	—	—	fairly strong	—
Dr. Jules Guyot	—	weak	—	rather weak
Orange Bergamotte	weak	—	—	(weak)
Winter Nelis	strong	—	—	—
(Trees on Hessle and Chaumontel still too small to show effects)				

Brackets ( ) indicate that trees are still rather small.

There is thus every reason to think that the variety used as intermediate does have a considerable influence on the vigour of the double worked tree. But it is by no means always the case that a vigorous variety used as intermediate will give a vigorous tree and *vice versa;* thus both Dr. Jules and Marie Louise seem to be somewhat dwarfed when worked on Catillac, a decidedly strong variety, and Dr. Jules is only moderate in vigour on Beurré d'Amanlis. Similarly, while Orange Bergamotte, a weak variety, has dwarfed both the varieties worked on it, Winter Nelis, by no means a strong variety, has given decidedly strong trees when used as intermediate for Souvenir du Congrès.

If we desired the greatest possible vigour, we should work Souvenir du Congrès on Fertility (it has not been tried here on Bellissime d'Hiver or Vicar of Winkfield), and Beurré Clairgeau on Bellissime d'Hiver (it has not been tried here on Fertility). But since quince stocks are used largely for their dwarfing effect, it is more likely that moderate vigour would be thought more desirable ; in that case we should probably use Beurré d'Amanlis as intermediate for either Dr. Jules Guyot, Marie Louise, or Souvenir du Congrès (it was not tried for Beurré Clairgeau). As a matter of fact, Beurré d'Amanlis is probably more widely used as an intermediate by nurserymen than any other variety.

If a still greater dwarfing effect were desired, the intermediate might be Orange Bergamotte. This has only been tried here as intermediate for Souvenir du Congrès and Marie Louise; in each case it has so far given the least vigorous of all the double worked trees. And it may be pointed out that this dwarfing effect is not similar to that caused by working the varieties direct on quince, at least in case of Souvenir du Congrès ; for the trees worked on Orange Bergamotte are uniformly dwarfed and all appear healthy, whilst those direct on quince either grow moderately well, or not at all, and these latter are unhealthy and soon die.

The question whether any one intermediate is likely to prove satisfactory for all varieties requiring double working cannot yet be answered. Beurré d'Amanlis has produced satisfactory trees of the three varieties working on it (Congrès, Dr. Jules and Marie Louise).

Catillac, however, while it has so far produced satisfactory trees when reworked with Beurré Clairgeau, seems likely to be less satisfactory as an intermediate for Dr. Jules and Marie Louise. Further than this we can say very little. But there are at least indications of special compatibilities and incompatibilities in various combinations of intermediates and second scions. It is by no means impossible that such a variety as Beurré d'Amanlis might prove unsuitable when used as intermediate for certain varieties not yet tried on it.

The number of fruit buds produced by the trees has not yet been large enough to give quite reliable results. The trees of Souvenir du Congrès planted in 1921-22 have for two years in succession produced the largest average

number of fruit buds where double worked on Conference (still more where single worked). But as the difference is due entirely to large numbers of fruit buds on three trees, the remaining seven trees having approximately the same number as the trees double worked on Winter Nelis and Beurré d'Amanlis, we cannot attach any importance to the result.

The trees of Beurré Clairgeau produced most fruit buds, in the winter 1925-26, where double worked on Conference and Catillac, and least on Bellissime d'Hiver, Vicar of Winkfield, and Josephine de Malines. The larger differences here show from 60 to 100 chances to one in favour of a similar result on repetition of the experiment. At the same time the trees of Dr. Jules Guyot produced by far the most fruit buds where double worked on Vicar of Winkfield and least on Bellissime d'Hiver and Beurré d'Amanlis. But there the variation from tree to tree is greater and the probability that the result would be repeated is smaller.

Nevertheless, there are already indications that the variety used as intermediate may to some extent influence the age at which the trees begin to bear.

Observations were made in the spring of 1926 on the date at which the flowers opened and fell. Owing to the warm weather, the whole period was very short, but enough was seen to suggest that in a slow cold spring there might be considerable differences. Curiously enough, whilst the single worked trees of Beurré Clairgeau were in blossom slightly earlier than any of the double worked trees, the single worked trees of Souvenir du Congrès were later than any of the double worked trees. These observations must be repeated before anything definite can be said.

Summary.

Experiments with double worked pears on quince stocks have shown :—

1. That Souvenir du Congrès and Beurré Clairgeau are clearly unsatisfactory within three years from planting, when worked direct on quince stocks (Angers). Dr. Jules Guyot and Marie Louise while none too good, are less clearly unsatisfactory at the same age.

2. That the variety used as intermediate in double working has a distinct influence on the vigour of the second scion. The results are shown in tabular form.

3. That this influence of the intermediate on vigour is not always directly correlated with the vigour of the variety used as intermediate.

4. That the variety used as intermediate probably has an influence on the age at which the tree begins to bear fruit.

ROOT STOCK EFFECT ON COLOUR AND SIZE OF APPLES.

By W. S. ROGERS.

Introduction.

This work on the effect of root stock upon Colour and Size of Apples—two very important attributes—was carried out by the writer while stationed at East Malling. The material used was that on the Stock trial plots of the Research Station. Very full records are kept of these plots, so that although the writer was only able to take records personally in 1925, previous figures were available which enabled results of more than one year's observations to be compared.

In the case of Colour, 1925 and 1924 crops are considered ; and in the case of Size, 1925, 1924, and some 1923 crops.

It must be emphasised that although the observations and records were most carefully made, they can only refer positively to the particular crop, under the particular circumstances existing, and in that season. Nevertheless, most interesting results have been obtained, that show certain distinct tendencies and demonstrate that there is scope for further investigation on these lines.

The trees in each separate experiment were planted at the same time, but as the stocks are of different vigour and precocity, the trees are naturally at different stages of maturity. It was to investigate the effect of this difference upon the fruits that this work was undertaken. It is of vital importance to the grower to know, when he plants trees upon a certain stock, what he can expect in six or seven years' time.

Of the sections that follow, Sections (1) and (2) deal with the effect of Root Stock on Colour and Size of Apples. Section (3) contains a full account of the methods used in working on Size and Colour. This is included since no published details of experimental methods of working on colour that have come to the writer's notice.

The experiments quoted were carried out not only to discover the effect of Stock on Size and Colour of fruit, but also to investigate the effect of pruning, manuring, and different soils. It will be found, therefore, in certain tables that a comparison can be made not only between different stocks, but between trees on the same stock pruned and unpruned, or on different soils (Table I), and manured with nitrogen or without nitrogen (Table IV). The discussion of these factors is being postponed until records of other years are available.

The writer wishes to record his thanks to Mr. R. G. Hatton, Director of the Station, for his kind assistance throughout. Also he thanks other members of the Research Station Staff, who made his time at East Malling not only very instructive, but very pleasant.

Section 1.

Colouring of Apples as affected by Stock.

It is no new idea that the colour of fruit is affected by stock. The following interesting extract is taken from " The Orchard and the Garden " (7), published in 1602 :

> " How Apples and other fruits may be made redde. If you will grafte upon a wilde stumpe, put the sprouts in Pike's blood, and then graft them, and the fruits will be red.
>
> "Otherwise take an apple braunch, and graft it upon an alder stumpe, and the apples will be red. Likewise if you graft them upon cherry trees."

T. A. Knight (4) in 1823 says :—

> " It is well known that a young Pear tree, when growing upon a Quince stock, affords fruit of brighter colours, and in some varieties, of larger size."

He suspects deterioration in quality however.

Lindley (5) says in 1855 :—

> "It is not merely upon the productiveness or vigour of the scion that the stock exercises an influence. Its effects have been found to extend to the quality of the fruit. . . . In the Pear, the fruit becomes higher coloured and smaller on the Quince stock than on the wild Pear. . . . Since the quality of fruit is thus affected by the stock, it seems allowable to infer that the goodness of cultivated fruits is deteriorated by their being uniformly worked upon stocks whose fruit is worthless ; for example, the Almond or the austere Plum can only injure the Peaches they are made to bear, the Crab, the Apple and so on.

It is interesting to note Hedrick and Tukey's remarks in 1924 (3). In a twenty-five years' fertiliser experiment on apple trees, the slight variations observed between the plots were noted to coincide with variations recorded before any fertiliser was applied. Having proved that bud variation was not a factor, they conclude

> " The discussion resolves itself naturally into one of stocks for apple trees, a subject about which little is now known but concerning which much may be expected in the future."

The influence of Stock on the colouring of Apples is a subject on which no published figures have come to the writer's notice. This is not very surprising, seeing that it is comparatively recently that true types of Paradise Stocks were sorted out at East Malling (1).

A summary of the results obtained from the colour grading of 1925 crops from the East Malling Stock Trial Plots is shown in Table I. The results from each plot are given separately, and it may be noted that there is a certain amount of variation in each type from plot to plot. This is only to be expected, since the plots are not all of the same age, and have had different treatments.

Plot 10 has trees planted in 1919. Bramley's grown as half-standards, Lane's as bush trees.

Plots 11, 12, and 13, were planted in 1920. All bush trees.

Plot 14. Planted in 1920. Has had no nitrogenous manure since 1919.

TABLE I.

Colour of Fruits as affected by Stock.

Year 1925.	PERCENTAGE OF SURFACE COLOURED on						
	Type I.	Type II.	Type VII.	Type IX.	Type X.	Type XII.	Type XIII.
At Malling : Bramleys (pruned) Plot 10 (6 trees)*	26.6	14.4	27.9	—	—	—	—
Plot 12 (4 trees)	16.0	14.4	19.6	24.9	—	14.2	—
Plot 13 (8 trees)	15.7	13.5	19.6	26.9	—	—	18.8
Plot 14 (16 and 13 trees) ..	17.0	18.4	25.6	—	23.8	—	—
(unpruned trees—) Plot 10 (6 trees)	29.4	19.4	34.3	—	—	—	—
Plot 12 (4 trees)	19.4	14.5	22.0	25.4	—	11.5	—
Lane's (pruned)— Plot 10 (5 trees)	23.2	11.3	26.5	16.1	—	—	13.6
At Swanley : Worcesters (4 and 5 trees) ..	54.2	50.2	—	65.9	—	—	—
At Wisboro' Green : Bramleys ..	46.2	45.2	—	49.1	—	—	—

* In every case the number of trees given indicates the unit of trees of each type.

A striking fact about Table I. is that on each plot there is distinct variation between apples from different stocks, and in almost every case their relative order of colouration is the same.

In each case the percentage of coloured surface is given, worked out as described in Section (3).

The number of stocks to be considered had to be limited, owing to lack of time, and four outstanding types were selected. These were :—Type I., English Broadleaf, a medium strong grower ; Type II., Doucin, semi-dwarfing ; Type IX., Jaune de Metz, very dwarfing ; and Type XII. or XIII. representing the very vigorous Paradise types. Several other types which appeared striking were added as the work progressed, notably Type VII., a medium strong stock (1). Unfortunately the crops from the very vigorous stocks Types X. XII. and XIII. were still so small that these figures cannot be considered as very reliable. However, there are indications that distinct variations in colouring of fruit may be found between different very vigorous stocks.

From the table it will be seen that Type XII. gave least colour, and the absence of colour on its few apples was quite striking. Next comes Type II., giving least colour of any dwarfing or semi-dwarfing type. Type I. follows, and, excluding for the moment the isolated cases of Types X. and XIII., Type VII. comes next, while Type IX. gives most colour of all.

The Lane's on Plot 10, besides giving the greatest variation between stocks, give a notable exception in the lack of colour on Type IX., which in this case does not give such good colour as Type I. It will be interesting to note in the future whether the effect of this stock upon Lane's is so markedly different from its effect on Bramley's. The only other exception is Type II. on Plot 14, where it was slightly better in colour than Type I.

On the variety Worcester Pearmain from Plots 12, 13, and 14, the order of colouration also appeared to be :—Best, Type IX., then Type I., Type II., and worst, Type XII. ; but unfortunately accurate figures cannot be quoted for these crops.

A plot of Worcesters on known stocks at Swanley Horticultural College, graded by the writer, gave the following percentages of colour :—

Type IX. 65.9%
Type I. 54.2%
Type II. 50.2%
(Type XII. was not grown on this plot.)

Also Bramleys on a Stock Trial Plot at Wisborough Green, graded by Mr. Hatton, gave percentages of colour as follows :—

Type IX. 49.1%
Type I. 46.2%
Type II. 45.2%

This shows incidentally how remarkably the Bramleys coloured in this locality, where the soil is heavy Weald clay.

Both of these results confirm the order found at Malling.

Results worked from colour grading of Worcesters in 1924, by Miss A. D. Mackenzie and Mr. H. C. Chapelow, of East Malling, are shown in Table II. This also agrees exactly with the results in 1925.

TABLE II.

Effect of Stock on Colour of Apples.

Worcester Pearmain, at Malling. Year 1924.

	Percentage of Surface Coloured on			
	Type I.	Type II.	Type VII.	Type IX.
Plot 13 (8 trees)	52.4	47.6	54.8	61.2
Plot 14 (16 trees)	42.4	39.0	48.9	—

Fig. 1 (see page 32) gives a fair comparison between the colour of apples from Types II. and VII. on Plot 10, Lane's. In each case the whole of size 3 is laid out in its colour grades, and it can easily be seen how much more colour there is on the apples from Type VII. than those from Type II.

These very distinct and consistent differences in colour of apples grown under similar conditions on different stocks, seem to indicate that the stock does have some influence on the colouring of the apple. It is a very fascinating problem as to exactly how this effect is gained ; whether it is a direct influence from the roots, or merely an indirect effect from the shape and type of tree. The latter would appear to be a possible explanation, for trees on Type IX. tend to be of an open nature without a great amount of leafy growth, while trees on Type XII. give most vigorous leafy growth at this age which thoroughly shades the apples from the sun. However, although the highest colour has been obtained on the most dwarfing stock, Type IX., Types I. and VII. which are more vigorous than Type II. have produced better colour than Type II. It also appears that some of the very vigorous stocks may produce fruit as highly coloured as that from the medium dwarfing stocks, though further observations are needed on this point. It may be a question of maturity of tree.

It would appear, then, that the colour of fruit may be modified to some extent by direct influence from the root system, apart from the vigour of the tree.

SECTION 2.

SIZE OF FRUIT AS AFFECTED BY STOCK.

The effect of stock on size of fruit has not passed unnoticed, as can be seen from the references given dealing also with colour. It will be noted that while Knight (4) considered Quince stock to give larger fruits, Lindley (5) remarks that it produces smaller fruits than the wild pear stock.

Pépin (6) has an interesting paragraph in the " Revue Horticole," 1848. After remarking on the deterioration in the size and quality of sweet Almonds on a bitter almond stock, he mentions an apple stock, "Pommier hybride ou Bâtard " of which he states :

> " Elle tient le milieu entre le Paradis et le Doucin. Les greffes faites sur ce Pommier produisent des rameaux très vigoreux, qui non-seulement fructifient très peu malgré les soins qu'on lui donne au moment de la taille et de l'ébourgeonnage, mais produisent, le plus ordinairement encore, des fruits petits et moins savoreux que ceux que fournissent les greffes placées sur les paradis ou les doucins."

i.e. Apples grafted on this stock make very vigorous growth but fruit very badly, and the fruit is small and of worse flavour than that from trees on Paradise or Doucin stocks.

Hatton (2) has already made some preliminary observations on variation between the size of fruits from different stocks. These are referred to later.

Some results from size-grading the 1924 and 1925 crops are seen in Tables III. and IV.

In each case the number of fruits in each size grade is given, with the total number of fruits. The percentages which these numbers represent are given below them.

It is important to consider the amount of crop with the size of fruits, for although no definite correlation between crop and size of fruits has been established, beyond certain limits undoubtedly a heavier crop tends to consist of smaller apples. It would be very useful to find a factor reconciling crop and size of fruit, but no such formula has come to the writer's notice. One point to consider in such a case would certainly be the size of the tree compared with the amount of the crop.

It will be noted in these two tables however, that the crops are fairly even, thus not unduly obscuring stock influence.

When comparing Plots 13 and 14, notice that Plot 14 has a total of sixteen trees on each type, while Plot 13 has eight trees on each type.

Considering Table III. first, Worcesters, for the year 1925. It will be seen that on Plot 13, Type IX. produced the highest percentages of larger sized fruits, 19.8% and 49.0% in the first two sizes. Type I., with a slightly larger crop, but with a larger frame to bear it on, comes next. Type II., with a similar crop to Type IX., is distinctly inferior in size, while Type XII. in spite of a very much smaller crop, has still smaller apples. On Plot 14, Types I. and II. gave similar results. Types IX. and XII. are not planted on this plot.

In 1924, however, the size grading gave the results shown below those for 1925. Here Type IX. is inferior to Types I. and II., though the order I., II., and XII. is maintained. This was the first reasonable crop for types I. and II.,

Table III.

Size of Fruits as affected by Stock. Worcester Pearmain, at Malling.

Year 1925.	Plot 13 (Nitrogen-manured).* Number of Fruits in size :— over 1. 2¾ in.	2. 2¾ in.	3. 2½ in.	4. 2 in.	Total.		Plot 14 (No Nitrogen).* Number of Fruits in size :— 1.	2.	3.	4.	Total.
8 Trees on Type I. ..	37	102	57	18	214	16 Trees on Type I ..	45	220	143	47	455
%	17·3	47·7	26·6	8·4		%	9·9	48·4	31·4	10·3	
Type II. ..	27	90	63	10	190	Type II. ..	20	219	192	39	470
%	14·2	47·3	33·2	5·3		%	4·3	46·6	40·8	8·3	
Type IX. ..	38	94	48	12	192	Type IX. ..	—	—	—	—	—
%	19·8	49·0	25·0	6·2		%	—	—	—	—	—
Type XII. ..	5	37	35	4	81	Type XII. ..	—	—	—	—	—
%	6·2	45·7	43·2	4·9		%	—	—	—	—	—
Year 1924.											
Type I. ..	13	62	49	27	151	Type I. ..	12	60	68	42	182
%	8·6	41·0	32·5	17·9		%	6·6	33·0	37·4	23·0	
Type II. ..	5	57	71	31	164	Type II. ..	7	44	104	63	216
%	3·1	34·7	43·3	18·9		%	3·2	20·2	47·7	28·9	
Type IX. ..	6	48	72	31	157						
%	3·8	30·6	45·8	18·8							
Type XII. ..	1	24	31	12	68						
%	1·5	35·3	45·6	17·6							

* See Introduction.

while Type IX. had cropped well before, but a similar irregularity is seen in Hatton's figures (7) for Lane's on Plot 10 in 1922-23: viz., in 1922, Type IX. had larger fruits than I. or II., and in 1923 it had smaller fruits than either. Lack of rainfall would not account for the lack of size in 1924, for that was a wet year. Possibly the lack of sunshine limited the amount of food which these small trees could obtain; but it is a curious point, which needs further investigation.

TABLE IV.

Size of Apples as effected by Stock.

Lane's Prince Albert, at Malling. Plot 11.

Year 1925.	Number of Fruits in size :— 1. over 3½ in.	2. 3½ in.	3. 3¼ in.	4. 3 in.	5. 2¾ in.	Total No.	Total weight. lbs.
20 Trees on Type I.	40	138	158	259	160	755	307
%	5.3	18.3	20.9	34.3	21.2		
Type II.	50	104	121	195	143	613	254
%	8.1	17.0	19.8	31.8	23.3		
Type IX.	91	118	135	176	136	656	287
%	13.9	18.0	20.6	26.8	20.7		
Type XIII.	34	104	105	161	98	502	213
%	6.8	20.7	20.9	32.1	19.5		

Year 1924.	over 3½ in.	3½ in.	3 in.	2½ in.	Total No.	Total weight. lbs.
Type I.	nil	24	94	64	182	61½
%		13.2	51.6	35.2		
Type II.	nil	26	167	85	278	83¾
%		9.4	60.0	30.6		
Type IX.	nil	71	493	374	938	267
%		7.6	52.6	39.8		
Type XIII.	nil	12	37	17	66	23¼
%		18.2	56.1	25.7		

Turning to Table IV., we see the results of sizing fruit from groups of twenty Lane's Prince Albert trees. These were planted in 1920, as maidens. Here again in 1925 the crops are fairly comparable. Type IX. has distinctly the largest fruits, Type XIII., a very vigorous stock, comes next, with a smaller crop, and Types I. and II. are about equal, but Type I. has over 100 more fruits.

In 1924 again a drop in the size of apples from Type IX. is seen. In this case however, Type IX. has three times the crop of any other type. Type XIII.,

with the smallest crop, has the largest apples. Type I. comes next, with more apples; and then Type II., with more apples again. Here probably the stock effect on size is completely masked.

It will be noticed from both tables that all fruit was much larger in 1925 than in 1924.

The 1923 crop on the Lane's on Plot 11 was as follows :—

Plot 11 Lane's.	Total fruits.	Average weight of fruits.
Type I.	27	5.5 oz.
Type II.	67	5.4 oz.
Type IX. ..	171	5.9 oz.
Type XIII. ..	5	4.8 oz. only two trees fruited.

In this case Type IX. has produced the largest apples as well as the largest crop. The order I., II., XIII., remains. Incidentally, this gives a good idea of the precocity of the dwarfing stocks.

The general tendency appears to be that while the most dwarfing stock, Type IX., frequently produces the largest apples, it fluctuates considerably. The inverse correlation between vigour of stock and size of fruit does not hold, however, in the case of Types I. and II., where the more vigorous Type I. appears to produce larger apples than Type II. While the very vigorous Type XII. has produced the smallest apples, Type XIII. now seems to produce well-sized apples, and it should not yet be assumed that all the very vigorous stocks will produce small apples. The earlier maturity of trees on dwarfing stocks obviously has some effect upon the fruits.

Section 3.

Details of Experimental Method used in Estimating Size and Colour.

(a) Size Grading.

The size of apples is an easily comparable characteristic, for it is a fairly simple matter to divide the crop into any number of size grades.

In the present experiments, the apples were sized on a simple form of hand-grader, consisting of two parallel pieces of wood, one of which is cut in quarter inch steps, and whose distance apart can be altered, as shown in the diagram (Fig. 2, page 32).

The result is to produce a series of gauges varying by quarter-of-a-inch. Below each size slit is a canvas chute leading to a container in which the apples may be collected without bruising.

There are two ways in which this grader can be used. Either the apple can be passed along from A. to B. (Fig. 2), passing over the narrower slits until

one large enough for it to drop through is reached; or else it can be passed between the gauges from B. towards A., until it reaches a point where it will go no further, when it is allowed to drop. The result is the same in either case. Perhaps the latter method gives less tendency to damage the surface of the apple.

With such graders it is usual to grade by the cheek measurement, i.e., the central axis of the apple from stem to eye will be kept parallel to the sides of the grading slits.

The number and weight of apples in each size grade can be recorded, and expressed as percentages.

In these records the measurement given for each size grade refers to the width of the slit through which the apples passed. For example Size 2, $2\frac{1}{2}$ in.; 3, $2\frac{1}{4}$ in.; 4, 2 in. would mean that apples of size 2 all passed through a $2\frac{1}{2}$ in. slit but were above $2\frac{1}{4}$ in. in size, apples in size 3 were below $2\frac{1}{4}$ in. and above 2 in., and apples in size 4 were all below 2 in. Size 1 consists of all apples above size 2, in this case all above $2\frac{1}{2}$ in.

The results given are worked from the number of apples in each grade, on the principle that each apple had the potentiality (though not necessarily the opportunity), of being a well sized fruit. To work results from the weights of fruit in each grade would give the large apples a higher proportionate value, though if all the results were worked this way they would be just as comparable.

Similarly the results on colour are worked from the number of apples in each colour grade, as the object in view was to find under what conditions each apple, or the majority of apples, tend to become well coloured.

(b) Colour Grading.

The Colour Grading presented rather more difficulty, but the problem was of considerable interest. The writer had to evolve his own methods; and it is in the hope that his experience may be of some use to others who may wish to do similar work that these methods are here described in some detail.

It is of course practically impossible to make inflexible standards of colour, and at present the only method of grading for colour is by inspection of each apple individually, from which the worker decides in which grade the apple should be placed. The number of grades of colour to be made needs to be within reasonable limits, for the sake of simplicity, but sufficient to give good indication of the real tendency of colouring; better for instance than a mere separation of say " well coloured " from " badly coloured " fruits. Four grades was the number selected by the writer. The standard, or amount of colour in each grade, would vary with different varieties of apple, the grades suitable for a Worcester Pearmain obviously being useless for a Lane's Prince Albert.

Method of Grading highly coloured varieties of Apples.

For highly coloured apples, including most dessert varieties such as Worcester, Cox, and Allington, the four grades were fixed as follows :—

Colour Grade 1. All apples over $\frac{3}{4}$ reddened.
,, ,, 2. ,, more than $\frac{1}{2}$ and less than $\frac{3}{4}$ reddened.
,, ,, 3. ,, more than $\frac{1}{4}$ and less than $\frac{1}{2}$ reddened.
,, ,, 4. ,, less than $\frac{1}{4}$ reddened.

The method of examination fixed for this system, to give greatest possible accuracy and speed, was to take the apple in the left hand, revolve it so that most red showed, turning it so that one edge of the reddening was just at the edge of the visible half of the apple. If the reddening did not extend over half the visible surface, the apple would be placed in Grade 4 (under $\frac{1}{4}$ coloured) (see Fig. 3). If the reddening extended beyond the centre line, but did not cover the complete visible half, it would be in Grade 3 ($\frac{1}{4}$ to $\frac{1}{2}$ coloured). If a complete hemisphere of red was shown, the apple would be above Grades 4 and 3 ; in this case the apple was turned so that this red half was away from the eye, and the further extent of reddened surface was inspected. If this did not pass the centre line, the apple would be in Grade 2 ($\frac{1}{2}$ to $\frac{3}{4}$ coloured), and if the centre line was passed, the apple would be in Grade 1 (over $\frac{3}{4}$ coloured). The method of holding the apple is shown in Fig. 4.

Fig. 5 shows the appearance of a typical box of Worcesters after colour grading.

Of course it frequently happened that the colour had irregular boundaries, or was in streaks, and in such cases the worker had just mentally to reduce the colour to terms of the standards given above. It is here that the human factor of error tends to be large, making it desirable that all the apples to be compared should be graded by one worker.

The further complicating factor of intensity of colour was as far as possible omitted, only the extent of reddening being taken into account. As a matter of experience, it was found that the intensity of colour varied comparatively little, certainly not to such a degree as the area.

Method of Grading Poorly Coloured Varieties.

With poorly coloured varieties, much lower standards of colour had to be fixed.

For Lane's, for instance, all apples over $\frac{1}{2}$ coloured were placed in Colour Grade 1, all between $\frac{1}{4}$ and $\frac{1}{2}$ coloured in Grade 2, all showing colour, but below $\frac{1}{4}$ coloured, in Grade 3, and all totally green apples in Grade 4. (See Fig. 3a.)

It saves some time to have a regular routine of working. The writer found it most convenient to have four boxes or trays in a row in front of him, at about

waist height, to contain the four grades ; and the trays of apples to be graded were placed on his left side. The apples were picked up in the left hand and examined, and were then placed in the correct tray by the right hand, while the left hand picked up another apple.

It is important to work in a good light.

One advantage of the grading by quarters, or 90° segments, is that this division can be judged fairly accurately by eye alone, no apparatus being necessary, and consequently speed in handling is facilitated.

Alternative Precision Method.

For cases where finer division is desired, or the amount of colour is not well adapted to measurement in 90° segments, the apparatus shown in Fig. 6 was devised by the writer. This apparatus is simply a gauge that will indicate accurately at a glance a number of equal segments on the apple.

The particular gauge illustrated divides the apple into five segments. Its construction is self-explanatory. Wooden pegs jut out at an angle from holes in a base-block. These holes are set out at equal intervals round a small circle described on the base. The base-block may be extended into a handle for holding by, but this is not important. Any number of segments may be made, such as six, seven, or eight. The five segments gauge gives quite easy working, for each segment is 20 per cent. of the whole. With this gauge if desired the colouring can be judged to the nearest 10 per cent.

When an apple is placed in the framework formed by the pegs (as shown in Fig. 7) the point where each peg touches the apple indicates the boundary of a one-fifth segment, or whatever it may be, of the surface. If one boundary of the colouring is made to coincide with one peg, then the number of segments into which the colour extends is readily seen, and the apple can be placed in the corresponding colour grade.

The grades can be arranged to suit the class of apple. With Green Bramley's the writer used the five segment gauge, but only made four grades. All apples over two-fifths, or 20 per cent. coloured, were placed in Grade 1 ; all between 20 per cent. and 40 per cent. coloured, in Grade 2 ; all coloured but below 20 per cent., in Grade 3 ; and all totally green, in Grade 4.

Though considerable speed in colour grading is acquired with practice, it necessarily takes time to consider each apple separately. It takes just as long to colour grade a dozen small apples as a dozen large ones.

At first an attempt was made to classify the colourings by comparison with some standard tints, such as the Repertoire de Couleurs of the Société française des Chrysanthémistes, but it was found very difficult to make any definite distinction between groups of apples of the same variety. Even where

distinct difference in appearance was visible, it was usually found that one group was merely a lighter shade of the same colour.

The reds were mainly Laque carminée passée, No. 106, and the green Vert jaunâtre, No. 291. This comparison was finally abandoned.

It is interesting to note that it is of some importance to grade all the apples in one experiment within a reasonably short time, since the colouring may increase quite appreciably and rapidly after picking. One group of apples was graded twice, an interval of three-and-a-half weeks being allowed between the gradings, with the results shown in Table V.

TABLE V.

Increase in Colour after Picking.

Lane's Plot 10. 1925.	Percentage of Total surface coloured on :— October 15th.	November 9th.	Increase.	Per cent. Increase.
5 trees on Type I.	15.3	23.2	7.9	51.6%
Type II. ..	7.6	11.3	3.7	48.7%
Type IX. ..	12.4	16.1	3.7	29.8%
Type XIII. ..	10.3	13.6	3.3	32.1%

It will be seen that in this short time the percentage of coloured surface increased considerably in all cases. Though the order of types was unchanged the increase varied from 29.8 per cent. to 51.6 per cent. above the original colouring.

Method of Working out Colour results.

Having got the number of apples in each known and specified colour grade, it was possible to take further steps towards obtaining easily comprehensible and comparable figures.

One method of summarising would be to express the number of apples in each colour grade as a percentage of the whole crop.

It is also possible however, where size grading has been done, and each size grade has been separately colour graded, as was done by the writer, to express the total colour of a tree or plot in one figure with great nicety. It is not too much to assume that the surface area of the apples (for surface is what one is dealing with in Colour grading), can be calculated from the formula $S=4\pi r^2$ (the surface of a sphere). The procedure is as follows :—

(1) Each size grade is graded for colour separately, as shown in the example below.

Lane's, 5 Trees on Type I. (Plot 10).

Size.	Number of Fruits in Colour Grade : 1.	2.	3.	4.	Total.
1. over 3½ in.	5	18	16	19	58
2. 3½ in.	6	18	24	34	82
3. 3¼ in.	3	16	14	22	55
4. 3 in.	4	24	26	58	112
5. 2¾ in.	0	8	16	36	60
Totals	18	84	96	169	367

All records were taken in this form by the writer.

(2) The surface area of each number of apples is then calculated by multiplying by its size factor, or $4\pi r^2$, the r in each case being half the average diameter of the size grade. This gives a table as shown below, and the totals at the bottom give the total surface in each colour grade, and of the whole crop.

Size.	$4\pi r^2$ factor.	Surface Area in Colour Grade : 1.	2.	3.	4.	TOTAL. sq. ins.
1. average diam. 3¾ in. ..	44.2	221	795	707	840	2,563
2. ,, 3⅜ in. ..	35.6	214	641	855	1,210	2,920
3. ,, 3⅛ in. ..	30.6	92	491	428	674	1,685
4. ,, 2⅞ in. ..	26.0	104	624	676	1,508	2,910
5. ,, 2½ in. ..	19.7	0	157	315	709	1,270
Totals	—	631	2,708	2,981	4,941	11,261

(3) Now (for Lane's)

Colour 1 is over ½ coloured, say average 0.65
,, 2 is ¼ to ½ coloured, say average 0.375
,, 3 is up to ¼ coloured, say average 0.125
,, 4 has no colour on Lane's 0.0

Therefore coloured surface in Colour Grade	1 is	631 × 0.65	=	410	sq. ins.
and ,, ,, ,,	2 is	2,708 × 0.375	=	1,014	,,
,, ,, ,,	3 is	2,981 × 0.125	=	375	,,
,, ,, ,,	4 is	4,941 × 0.0	=	0	,,
This gives a total coloured surface of				1,797	sq. ins.

which, out of a total surface of 11,261 sq. ins. is **15.9** per cent.

If only the percentage of coloured surface is required the factor 4π can be omitted, since it is common to both sides of the fraction, and it makes the working much simpler to do so. In this case the numbers can be converted to square inches at any point by multiplying by 4π.

It will be noted that this actual percentage is a comprehensible figure, from which all variable factors such as standard of size and colour grades have disappeared.

The writer does not doubt that this method of working size and colour grading together gives the truest possible representation of the facts.

The amount of calculation which is required, however, rather precludes the application of this method where the number of cases to be considered is very large. Consequently the writer had recourse to a simpler method, which, while not theoretically so ideal, gave results practically as good.

Simpler Method of Calculation of Colour.

This was to omit the size factor altogether, and multiply the number of apples in each colour grade by the average percentage of colour in that grade; in fact the number of apples in each colour grade was expressed in terms of wholly coloured fruit, and the sum was given as a percentage of the total number of fruits.

By this method the case worked above would appear thus:—

	Number of Fruits in Colour Grade.	× Average Colour of Grade.	= Coloured Equivalent.
Colour Grade 1	18	× 0.65	= 11.7
,, 2	84	× 0.375	= 31.5
,, 3	96	× 0.125	= 12.0
,, 4	169	× 0.0	= 0
	367		55.2

55.2 out of a total of 367 equals **15.1** per cent.

This would be just as good as the previous method if the colouring were evenly distributed throughout the different sizes, but as a matter of fact this is not always the case.

In Lane's for instance, it is quite noticeable that the larger apples are better coloured than those of smaller size. An example of this correlation, contrasted with the lack of correlation between Size and Colour of fruits of Cox's is shown in Table VI.

TABLE VI.

Relation between Size and Colour, on Lane's and Cox's.

Lane's (5 Trees on Type I.).

Size.	Percentage of Fruits of each size in Colour Grade.	
	1.	4.
1. over 3½ in. ..	30.0	8.0
2. 3½ in.	11.9	14.5
3. 3¼ in.	5.9	24.7
4. 3 in.	2.6	33.8
5. 2¾ in.	1.2	49.0

The Lane's showed distinct correlation between size and colour of fruit, though not always so strikingly as above.

Cox's (4 Trees on Pruning Plot).

Size.	Percentage of Fruits of each size in Colour Grade.			
	1.	2.	3.	4.
1. over 2¾ in.	6.3	56.2	25.0	12.5
2. 2¾ in.	4.7	40.6	46.9	7.8
3. 2½ in.	5.3	45.5	37.8	1.41
4. 2 in.	not graded.			

The Cox's showed no obvious correlation between colour and size of fruits.

The difference in final results, even in Lane's, between the two methods of calculation is not very large however, as can be seen from the illustrations worked on both methods from the same figures, i.e., 15.9 per cent. and 15.1 per cent.

In any case, since all the results were worked on the same method, they are equally comparable.

Summary.

Section (1). Figures are here presented showing the effect of Stock on Colour of Apples of three varieties—for two years in the case of one variety, and for one year in the case of the other two varieties—on three different soils. It is shown that the very dwarfing stock Type IX. has usually produced most colour on the fruits, but Type II. has tended to give less colour than the more vigorous Type I. There are indications that there may be considerable variation between the colouring effect of different very vigorous stocks.

Section 2. Figures are given showing the effect of Stock on Size of Apples of two varieties, for two years in one case, and for three years in the other. It appears that Type IX. gives the largest fruits in some years, but fluctuates considerably. Type I. has given larger fruits than Type II.

Section 3. Details are given of the experimental methods used in grading for size and colour, and various methods of working out the results are discussed.

It is noted that the colour of apples may increase considerably after picking, and an example is given of actual increase observed in three weeks.

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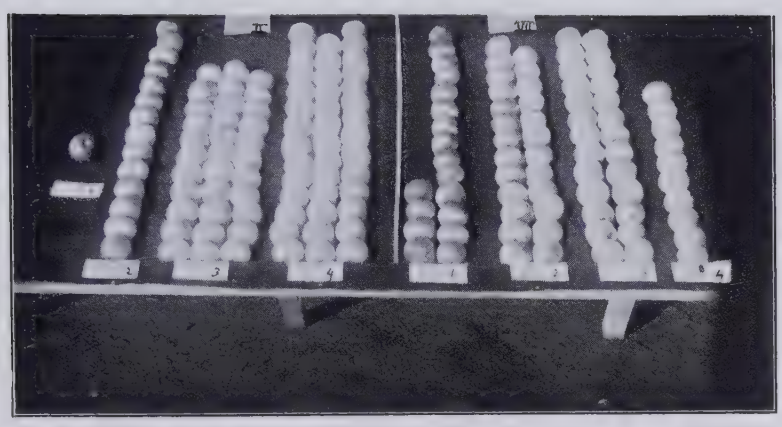
(5) *Lindley, J.* Theory and Practice of Horticulture, 1855, p. 355.

(6) *Pépin.* Revue Horticole, 1848, 2, p. 183.

(7) *The Orchard and the Garden.* Anonymous, London, 1602.

Fig. 1.



Type II. Type VII.

Colour 1. Colour 2. Colour 3. Colour 4. Colour 1. Colour 2. Colour 3. Colour 4.

Lanes on Types II. and VII. laid out in colour grades.

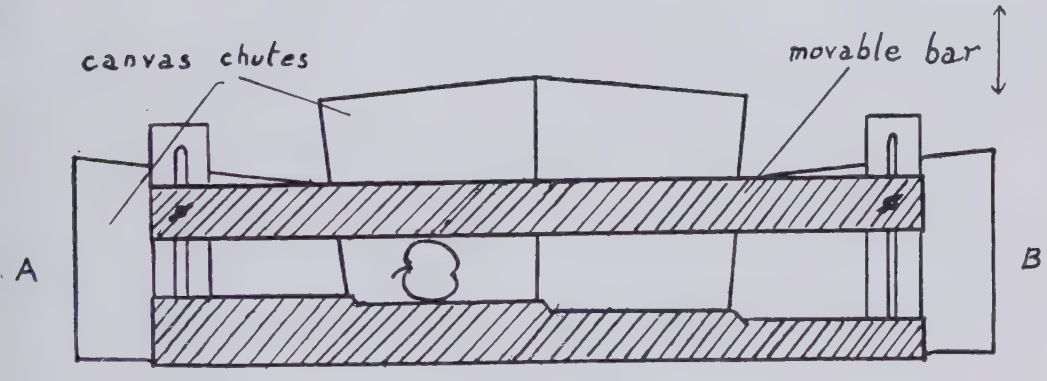


Fig. 2. (Not to scale).

Plan showing hand sizer used for size-grading apples.

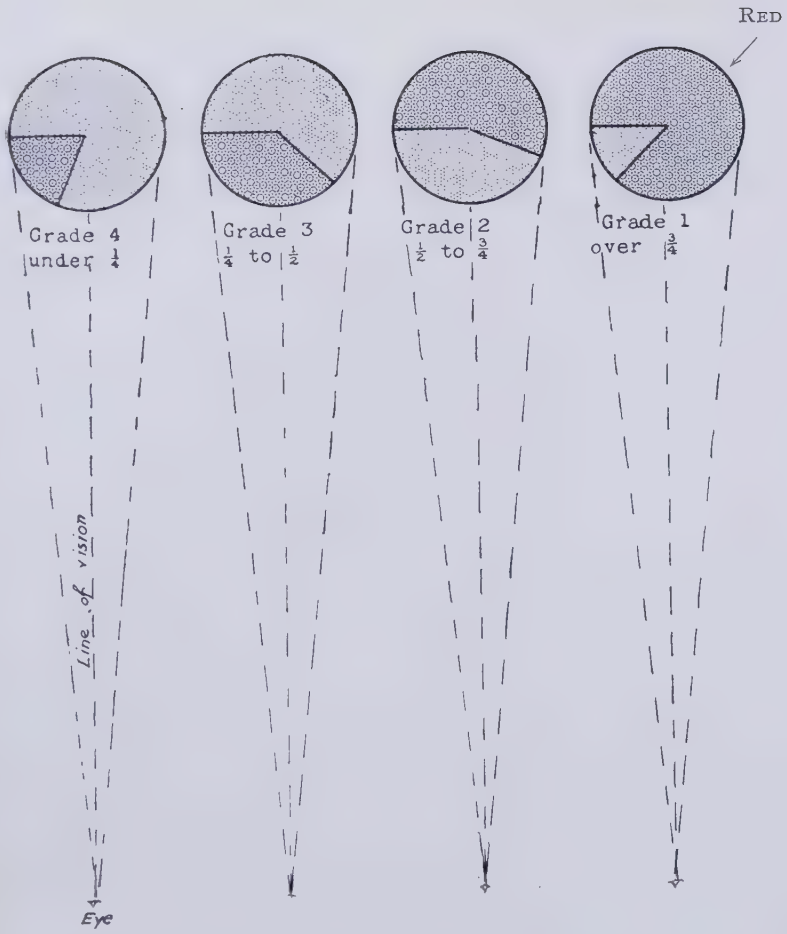


Fig. 3. Diagrammatic plan showing standards of colour grades for well coloured varieties.

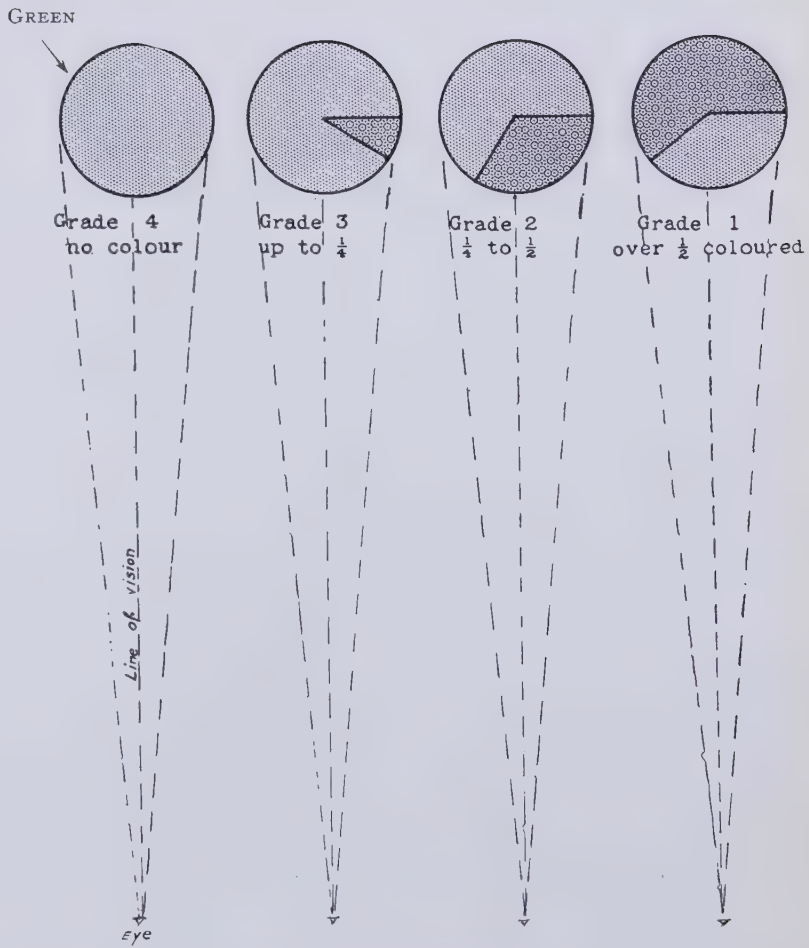


Fig. 3*a*. Diagrammatic plan showing standards of colour grade for poorly coloured varieties.

FIG. 4. Method of holding apple for colour grading.

FIG. 5. A typical box of Worcesters after colour grading.

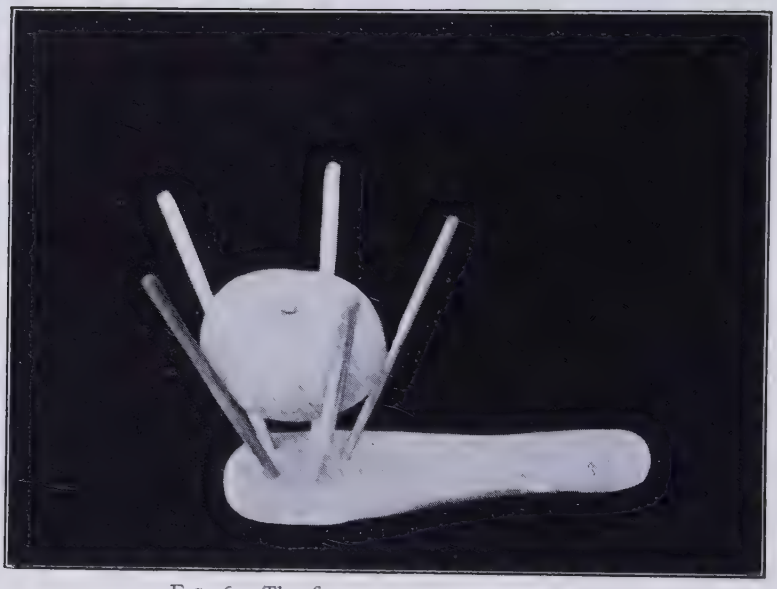


FIG. 6. The five segment colour grader.

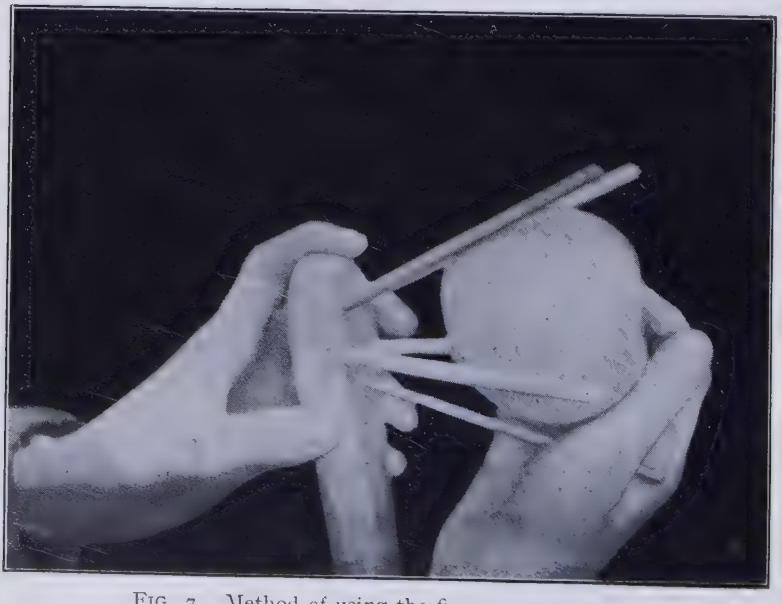


FIG. 7. Method of using the five segment grader.

THE INCIDENCE OF "DIE BACK" DISEASE IN PLUM TREES.

By J. AMOS, R. G. HATTON and A. D. MACKENZIE.

Some six acres of young plum trees, all raised in the nurseries of the Research Station, were planted out during the winters of 1921 and 1922. The first planting, known as Plot 20, consisted of 464 one year old Plum trees of ten varieties worked upon some nine different rootstocks. The rootstocks had been bought in from ordinary commercial sources, but were identified and rogued before working—and with the exception of eighty-seven St. Julien, seventy-eight Myrobolan and eight Black Damas which were seedling stocks, they had been vegetatively raised.

The different varieties upon each rootstock were planted in at least two or more different situations upon a piece of ground which was believed to be exceptionally uniform and which had been cropped and manured evenly for a year previously. The soil is a deep well drained one over the Kent Ragstone. The young trees were headed for half standards at 4 ft. 6 in. and were leader pruned for three years subsequently.

They received annually a fairly generous manuring, consisting mainly of London dung or shoddy, supplemented by a complete artificial fertilizer when any vegetable crop—such as potatoes—was taken from the intervening alleys.

Whilst in no way making excessive growth, the trees grew notably healthily, yet in 1923 individuals began to die out completely with the trouble now generally referred to as " die back." The general symptoms shown by the diseased trees were those described by Miss D. M. Cayley in her article " Fungi associated with ' Die back ' in Stone Fruit Trees,"* so that it is not necessary to detail them here.

All the trees referred to in this paper were examined individually by Dr. H. Wormald and diagnosed as typical cases of " Die back."

A second area known as Plot 21, adjacent to Plot 20 on the north, was planted a year later with 464 maiden or two-year feathered plums all of which had been raised at the Research Station, upon rootstocks, all vegetatively reproduced in its own nurseries. On this occasion only four varieties were planted but some fifteen distinct rootstocks were under trial. The trees were pruned and cultivated as on Plot 20.

The ground has received very similar treatment to Plot 20, and has never exhibited any striking lack of uniformity. Nevertheless a similar serious outbreak of " Die back " has supervened.

* *Annals of Applied Biology* X, 1923, pp. 253-275.

The incidence of the disease upon both plots has been closely followed up ever since its first appearance, with special relation to the possible differing degrees of susceptibility of different plum varieties and with different combinations of stocks and scions.

On Plot 20, out of a total of 464 trees, twenty-five have been attacked and killed by " Die back " up-to-date. The general distribution of the attack does not suggest anything very definite, although one side of the plot is more severely affected than the other.

If a line be drawn from north to south through the centre of the Plot, six cases fall to the east of the line and nineteen to the west. If a similar line be drawn from east to west, twelve cases fall one side and thirteen the other.

Table I. gives the percentage of trees attacked of each variety.

TABLE I.

Percentage of Trees of Different Varieties, affected on Plot 20.

	No. of Trees on Plot.	Per cent. affected by disease.
Cherry Plum (Myrobolan)	35	3.0
Black Bullace	32	0
Prune Damson	32	3.0
Yellow Egg (Pershore)	64	1.5
Czar	64	7.8
Victoria	88	10.3
Giant Prune (Burbanks)	32	12.5
Belle de Louvain	40	2.5
Denniston's Superb (Gage)	45	2.2
Purple Egg (Martins)	32	0

This table does seem to suggest that there are real differences in the susceptibility of different scion varieties—Giant Prune, Victoria and Czar stand out as notably susceptible, whilst Purple Egg and Black Bullace have not become affected at all.

When the incidence of the disease is studied in relation to stock and scion combinations, there appears no indication at all that the disease is worse on any particular rootstock. For instance, five trees of Czar are killed, one of each of the following stocks, Myrobolan, Pershore, Common Mussel, Brompton and Brussel. Four out of five of these stocks generally suit Czar admirably. On the other hand the unthrifty trees on Brussel have suffered no worse, and those on Common Plum, a stock most unsuitable to Czar, show no casualty at all from " Die back."

Again the nine trees of Victoria which are killed are distributed on five different stocks as follows, two on Pershore, one on Brompton, two on Brussel, three on Seedling St. Julien and one on Seedling Myrobolan.

If all the trees budded on each stock are grouped together, the percentages of trees killed as shown in Table II. do not offer any greater evidence of selective attack.

TABLE II.

Percentage of Trees on Different Rootstocks, affected on Plot 20.

Rootstock on which trees are worked.	No. of Trees.	Per cent. affected by Disease.
Pershore	83	6
Brussel	58	·5
Brompton	85	·7
Common Plum	32	0
C. Mussel	17	6
B.L.S. Mussel	6	0
Myrobolan (Seedling)	78	4
St. Julien (Seedling)	87	5
Black Damas (Seedling)	8	37*

* Too few trees are involved for this figure to have any real significance.

The attack on Plot 21 has been far more severe, and for this reason a complete plan of the plot showing the trees killed by "Die back" is reproduced. The plan is noteworthy for two reasons. It shows the high degree of immunity of River's Early Prolific and President as compared with Victoria and Czar.

Although the rows are alternated, the disease has singled out the rows of Victorias in particular for attack. Out of a total number of 241 Victorias, seventy-eight have been killed already—i.e., 30 per cent. Of the eighty-seven Presidents and eighty-seven Prolifics, only one tree of each has succumbed. Of the forty-nine Czars four trees have died.

Table III. analyses these figures for each variety upon each rootstock.

The figures seem to confirm those of Plot 20 in suggesting that whilst the attack takes place more or less indiscriminately upon any rootstock, the susceptibility of scion varieties is markedly different.

With regard to the possibility of rootstock being a primary cause of the trouble, it may be added that although the roots of over one hundred diseased trees have been carefully examined there was only one in which any sign of root unhealthiness could be traced. The development of the roots for any

TABLE III.

Percentage of deaths caused by "Die back" on Plot 21, on different varieties of rootstock.

	Pershore.	Brussels.	Brompton.	C. Plum.	C. Mussel.	B. L. Mussel.	N. L. Mussel.	B. C. Mussel.	Kroosjespruim.	Cluster Damson.	Mariana.	Myrobolan A.	Myrobolan B.	Myrobolan C.	Myrobolan D.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Victoria	40	30	31	37	44	30	—	22	43	—	53	20	37	11	40
Czar	—	—	—	0	—	—	0	—	—	20	—	—	9	—	—
President ..	0	0	0	12	0	0	—	—	—	—	0	—	0	—	—
Prolific ..	0	9	0	0	0	0	0	—	—	—	—	—	0	—	—

particular stock was quite normal. Examination showed as a matter of fact that the trouble had very rarely passed below the point of union with the bud or graft. These trees had been lifted and examined within a short time after the death of their "heads."

In the second place the map shows that the distribution of the disease appears to have no relation whatever to its situation upon the plot. If the plot be divided evenly from north to south, it will be found that forty-five trees dead lie to the eastward and thirty-nine to the westward. Similarly if it be divided centrally from east to west, forty cases are on the northern half, and forty-four on the southern.

Though there are a number of cases where adjacent or closely adjacent batches of trees have died, the evidence of infection centres cannot be claimed to be by any means conclusive. On the other hand, stock and soil have obviously played an even lesser part.

Whilst it is outside the scope of this paper to discuss the possible fungi, bacteria or insects that may be responsible directly or indirectly for the disease, it may be chronicled for the information of investigators that in some sixteen cases the "Shot Hole Borer" Beetle (*Anisandrus dispar. Fab.*) was found at the time of examination to be present in the trunks, as well as the usual fungi, etc. On several occasions, also, a wood-boring beetle, *Clytus arietis* (*Linn.*), was found to be active upon the plots, and was actually observed to be engaged in its boring operations upon an apparently healthy tree.

The writers of this paper are particularly beholden to Dr. Wormald for making the detailed examinations of the trees, and to Miss M. Gillman for drafting the map of the Plot.

DISTRIBUTION OF DIE-BACK PLOT 21.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
XVI. CZAR	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
XV. VICTORIA	P	P	P	P	P	R	R	R	R	R	N	N	N	N	N	M	M	M	M	M	G	D	G	D	G	D	G	D	G
XIV. "	M	M	M	M	M	N	N	N	N	N	R	R	R	P	P	P	P	P	N	L	N	L	N	L	N	L	N	L	D
XIII. "	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	K	K	K	K	K	K	D	B	
XII. PRESIDENT	D	D	D	D	F	F	F	F	F	F	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	D	D	D	D
XI. VICTORIA	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
X. PROLIFIC	D	D	D	D	D	D	D	N	N	N	N	N	D	D	D	D	N	N	N	N	N	N	S	S	S	S	S	S	S
IX. VICTORIA	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
VIII. PRESIDENT	E	E	E	E	E	E	N	N	N	N	N	C	C	C	C	C	C	C	B	B	B	B	B	B	A	A	A	A	A
VII. VICTORIA	E	E	E	E	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	B	B	B	B	A	A	A	A
VI. PROLIFIC	S	S	S	E	E	E	E	E	F	F	F	F	F	C	C	C	C	C	C	B	B	B	B	B	A	A	A	A	A
V. VICTORIA	H	H	H	H	H	S	S	S	S	S	S	S	S	S	D	D	D	D	D	D	N	N	N	N	F	F	F	F	F
IV. PRESIDENT	A	A	A	A	A	A	A	B	B	B	B	B	C	C	C	C	C	C	E	E	E	E	E	E	F	F	F	F	F
III. VICTORIA	F	F	F	F	F	N	N	N	N	N	D	D	D	D	D	S	S	S	S	S	S	S	S	S	S	H	H	H	H
II. PROLIFIC	A	A	A	A	A	B	B	B	B	B	B	C	C	C	C	C	C	C	F	F	F	F	F	F	E	E	E	E	E
I. VICTORIA	A	A	A	A	A	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	E	E	E	E	E

A = PERSHORE
B = BRUSSELS
C = BROMPTON
D = C. PLUM
L = CL. DAMSON
E = C. MUSSEL
F = B.L. "
H = BASTARD C. "
K = KROOSJESPRUIM
G = N.L. MUSSEL
M = MYROBOLAN A
N = " B
R = " C
P = " D
S = MARIANA

EXPERIMENTS UPON THE REMOVAL OF LATERAL GROWTHS ON YOUNG APPLE TREES IN SUMMER; THE EFFECT ON STEM AND ROOT DEVELOPMENT.*

By R. G. HATTON and J. AMOS.

It is the common practice amongst nurserymen in this country, when they are "running up" young fruit trees for standards and half-standards, to allow the young growths, which break all up the stem, to remain growing naturally, or sometimes pinched back, during the tree's early life in the nursery.

The considerations which have led to this practice are probably many. These "feathered" trees, as they are called, are very convenient for adapting to any desired height or form, and it is an expensive business to keep a clean stem, a process which may not be of any value to the tree. Tree raisers claim, on the contrary, that a stouter stem and sturdier tree result if the "feathers" are left for two or three years.

Although we were fully conscious of commercial practice, we had always developed, in our nursery, the system of keeping all the young shoots below the head of the tree (i.e., the main leader in a two year old, or main branches in a headed three year old) rubbed out. This was convenient on experimental grounds, for, where we were desiring to take a measure of annual growth, it was obviously easier to concentrate that growth into a single leader or four or five main branches rather than to let it dissipate itself all over the tree. We also thought it likely, if we prevented the "feathering" taking place on the stem, that that growth "energy" might go as an addition to the head.

Since, from several other points of view, we were studying the effect of various degrees of pruning upon the tree's roots, we decided to submit a very suitable series of nursery trees to differential treatments, in order to find out exactly what was going on in the "feathered" as compared with the "defeathered" or "clean" tree.

Material Used and Treatments Compared.

We had, at the time, in our Nursery, several adjacent rows (three feet apart) of one year old trees of Allington Pippin and Newton Wonder Apples, budded (in July, 1922) upon a series of selected very vigorous stocks (which had been planted *in situ* at one foot apart the previous February). In all, there were approximately twenty trees of each, upon nine varieties of rootstock. It was planned to run these trees up for standards, and to treat every alternate tree on

* Reprinted from the *Journal of Pomology and Horticultural Science*, Vol. VI., No. 1, with permission.

the " defeathering " method. Thus, trees, 1, 3, 5, etc., were allowed to send out normal lateral shoots on their second year stems (1923). These shoots, however, were stopped at the fifth leaf, and, if any secondary growth resulted, again at the second new leaf. This series will be referred to as the " Feathered " trees. Trees 2, 4, 6, etc., had all these growths rubbed out, as far as was practicable, as soon as they appeared. This series will be called the " Clean " or " Defeathered " series. In both cases the current season's (1924) main leader growths, which very rarely feathered appreciably, were left to extend untouched.

Thus, approximately ninety trees of Allington Pippin and ninety of Newton Wonder received each treatment, wherever available, ten trees of each on every stock being treated in each way. However, since the results obtained proved decisive and confirmatory upon every type of stock, we can from the outset consider the four groups of ninety trees as four units. We feel, however, that it is worth putting on record the fact that the dfferences between Clean and Feathered trees were very much greater on some varieties of stock than on others. Since in every case but one (i.e., Type I.) these differences are consistent for both Allington and Newton, it is at least probable that this has some significance from a root stock point of view. A glance at the Appendix, giving the complete figures, will show this.

Finally, it should be pointed out that the two varieties, with which we were working, were admirably suited to supplement one another in view of their contrasting " feathering " habits. Whilst Allington Pippin tends to make long somewhat whippy laterals profusely, Newton Wonder normally produces few laterals, but short rosettes of leaves in places, and bare patches of stem in others.

As our results will show, this was a very fortunate selection, since the variety more prone to " feathering "—Allington—demonstrates more effectively the adverse results of " defeathering."

The year was a very propitious one in the Nursery, and neither insect nor fungus attack intervened to upset the normal development of the trees.

At the end of the growing season all the trees were lifted in order, and the very greatest care was taken to preserve the roots intact as far as possible.

The sets of trees were then subjected to an analysis designed to detect the relative increment of each. Table I. summarises this analysis.

Differences in Total Weight of Tree.

The first object was to discover whether there was any difference in total weight between the feathered and clean series, and, for this purpose, the feathers had to be removed before weighing. As will be seen in Table I. (column 5, Weight of Feathers) even the clean trees were found to have grown a few side shoots, late in the season, which had been missed. These are recorded for sake of accuracy,

TABLE I.

Average Measurements and Weights, at two years, of 90 trees "Clean" grown, and 90 left "Feathered" of two varieties.

	Maiden Growth in cms.		Leader Growth during year of treatment (2nd) in cms.		Weight of whole tree without "Feathers" in grammes.		Weight of "Feathers" in grammes.		Girth at "collar" in mms.		Girth at 2 feet in mms.	
	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."
Allington .. .. (on 9 Stocks).	97	96	96	94	456	599	21	57	64	71	42	43
Newton Wonder .. (on 9 Stocks).	95	98	87	88	513	627	14	47	70	75	44	46

but it must be remembered that they were few and far between, and had not the chance of operating throughout the season.

It is interesting to note in Table I. (column 2, Maiden Growth) that the trees started out, at least in growth, as a remarkably even series, although they had grown untouched during 1923. By the end of the second year, as is shown in Table I. (column 4, Weight of whole tree), the different treatments had very materially altered the balance in favour of the " Feathered " series. In the case of Allington Pippin, the trees which had been allowed to feather averaged 1.43 grammes more weight per tree ; in the case of Newton Wonder, 114 grammes per tree. As will be seen later, this increase in weight cannot be accounted for by any very significant increase in growth of new head, but mainly by better developed root systems and some stem thickening. The girth of stem, taken at the collar, i.e., just above the union, appears distinctly in favour of the feathered trees. Although the actual differences are small (see Table I., column 6, girth at collar), 7 and 5 millimetres, in favour of the Feathered trees, it must be remembered that these were only two year olds. Since the difference is constant throughout the series, it must add to the significance. The difference is more obvious at the collar than at two feet.

Increment in New Leader Growth.

Finally, Table I. seems to modify if not entirely dispose of our idea that, by concentrating the growth into the head of the tree, we should get an appreciably greater length of wood there. Whilst Table I. (column 3, Leader Growth) does show a slight difference in favour of the " Clean " trees in the case of Allington Pippin, the result is reversed in the case of Newton Wonder. This may be a real difference due to the distinct types of feathering normal to the two varieties, and already described.

If the figures given in detail in the Appendix be examined in the case of Allington Pippin, it will be seen that in seven cases out of nine, the balance is in favour of the " clean " trees, but the individual differences are admittedly small, and their significance may be questioned.

Effect on Root Development.

As soon as we began to examine and compare our two series of trees, it became obvious that the " de-feathering " had acted detrimentally upon root development, and we made general notes to this effect throughout. But in order to get measurable proof of our observations, we made certain root analyses on three series of Allington Pippin trees, on three different stocks.

These can be taken as typical examples, though, all through, the Allington Pippin trees showed greater differences in root development between clean and feathered than did the Newton Wonders.

Table II. illustrates the situation well.

TABLE II.

Effect of "de-feathering" Trees, during growing season, upon Root Development.

	Total Root Spread in cm.		Weight of coarse roots in grammes.		Weight of Fibre in grammes.		Total weight of Roots in grammes.		Coarseness of Roots.			
									Below 8 mm.		8 mm. and above.	
	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."	Clean.	"Feathered."
Allington on Type X. .. (Average 5 trees each).	67	78	52	83	16	22	68	105	5	5	5	8
Allington on Type A. .. (Average of 7 trees each).	77	79	67	95	13	18	80	113	7	7	5	6
Allington on Type C. .. (Average of 5 trees each).	74	94	72	118	8	14	80	132	8	11	5	7
Average for all ..	73	84	64	99	12	18	76	117	7	8	5	7

Column 2 shows a remarkable difference in root spread of 11 cm. per tree, on the average, in favour of the Feathered Trees.

The roots were then cut off the trees and graded into "Coarse Roots" (4 mm. and above in diameter), and "Fibre" (under 4 mm. in diameter) on a definite basis. Here again, especially in the case of Coarse roots, there is a remarkable average increase of 35 grammes per tree on the Feathered series (see Table II., column 3).

The average total weight of Roots (see Table II., column 5) again shows the difference very well, i.e., 41 grammes per tree in favour of the Feathered. The last column of Table II., comparing the number of roots below and above 8 mm., seems to point to the chief increase being in the coarse roots. These effects of pruning, for "defeathering" is after all merely a form of summer pruning, during the growing season, are an extremely encouraging supplement to the results we published in our Annual Report for 1923 on "Some Factors Influencing Root Development" (see pages 113-115).

Ultimate Effect upon the Development of Transplanted Trees.

It is as yet too early to say much about the ultimate influence of these differences in the trees as they left the Nursery upon the developed trees in the orchard. Sets of approximately ten trees of each variety, on each stock, were planted out (in two positions) permanently, and were headed back to a uniform height of $4\frac{1}{2}$ feet. The wood growth made subsequently, in 1925, has been measured, and the girth of each tree, at 2 feet, again taken. Table III. shows that the results are not as startling as might be anticipated, though the balance of new growth and girth increment are slightly in favour of the "Feathered" trees.

Table III.

Subsequent Effect of Nursery Treatments upon Trees after Transplanting and "Heading back" (third year).

	New Wood Growth in cms.		Girth at 2 feet in mms.	
	Clean.	"Feathered."	Clean.	"Feathered."
Allington .. .. (On 9 stocks).	164	171	49	53
Newton Wonder .. (on 8 Stocks).	128	132	54	56
Average of Both	146	152	52	55

It remains to be seen whether the differences will be accentuated or the reverse, now that all the trees are permanently defeathered below the head.

General Conclusions.

In any case, our experiments seem to have a very practical bearing on several problems. There now exists actual proof of the fact that, in order to raise the sturdiest and weightiest nursery tree, the young trees should be allowed to " feather," especially as the total residual growth is not materially increased, if the " feathers " are kept rubbed out.

From the point of view of summer pruning or pinching, so frequently recommended for restricting garden trees and those making too exuberant growth, it seems probable that, if this almost complete removal of lateral shoots has had such a marked effect, the removal of lesser portions may be expected to have some effect, and check the growth development of the tree.

Finally, whilst it is not the place here to digress into theories as to what is taking place in the tree's balance, it seems certain that these results will add at least one more link in the chain of experiments designed to study the root shoot ratio in such plants. The striking gradation of effect shown most in root weight and development, then in stem increment at the collar, less at two feet and least of all in the growth of head is very suggestive.

The writers would especially like to thank Messrs. F. Cheal and M. Tydeman who were closely associated with them in taking the somewhat elaborate and detailed records, on so considerable a series of trees. Their thanks are also due to Dr. R. C. Knight, for his general interest and advice and to Mr. N. H. Grubb for giving the time to work out many of the " probable errors." This enables them to add the following paragraph dealing with the measure of reliability of the figures and to indicate the " probable errors " for individual groups of trees, for several of the most important records.

Reliability of the Figures.

Appendix B, Tables a and b, gives the figures for the sets of trees of Allington Pippin and Newton Wonder on each variety of root stock separately, together with their Probable Error. The size of these probable errors is extremely encouraging when the comparatively small numbers of trees is taken into account.

In the case of Table a, average weight in oz. per tree, if we adhere to the standard we have suggested elsewhere, and ignore those experimental differences which are less than 3.2 times their probable errors, we find that 11 out of 18 series still show significant differences in favour of the Feathered trees. (These are shown on the Table in Black Type.) The differences range from 3.3 times the probable error up to 7.5 times, so that the chances in favour of a repetition of the results under similar conditions are very large. Three other cases come very close to our standard.

If the individual tree figures for the two series (clean and feathered) be taken for each variety (Allington and Newton) on all stocks, and if the weight of each tree is expressed as a percentage of the mean or average of the Clean series for its particular stock, the probable errors are still further reduced and the significance greatly enhanced.

In the case of Allington, where series of 85 and 79 trees are actually compared, the difference in favour of the feathered series works out at 14 times its probable error.

Even in the case of Newton Wonder, where series of 82 and 77 trees are being compared, and where smaller differences were to be expected, the difference is still over 8 times the probable error.

Again, if we examine the average girth at collar in mm. given in Table b, we find the statistical analysis again encouraging. Here out of 18 actual differences, no less than 12 stand our criterion of showing differences ranging from 3.4 to 8.2 times their probable errors. Two further cases come very near to being significant.

If, as before, the individual trees in each series are brought to a " common denominator " for comparison, the reliability of the experiment is still further emphasised, the difference working out at 12 and 9 times their probable errors, for sets of trees of 85 and 79 and 82 and 77 respectively for Allington and Newton.

Since the actual differences in the case of " girth at two feet " and of " new leader growth " were so small and inconsistent, it was not felt worth while to examine these figures in greater detail.

Summary.

1. The " Defeathering " in summer of the stems of young trees has been shown to affect the tree's weight and girth adversely.

2. This " defeathering " also much restricts the development of the tree's roots.

3. On the other hand, it seems clear that the remaining leader growths are not very materially strengthened.

4. Generally, trees allowed to feather in the nursery, show some slight gain in growth the year after transplanting.

5. These facts have a practical application both in the raising of young trees, and summer pinching practices. They also shed some light on theoretical considerations of the root shoot ratio.

Appendix A.

Details Compared for each Treatment on each Stock.

ALLINGTON PIPPIN (units of approx. 10 trees).

On Stock Type.	Maiden Length before treatments.		Second Year growth.		Total Weight.		Girth at Collar.		Girth at 2 ft.	
	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.	Clean.	Feathered.
I.	102	101	95	84	48	66	64	73	43	46
X.	96	101	87	85	40	57	61	70	39	44
XII.	90	92	103	95	48	63	66	73	41	43
XIII.	91	87	111	102	51	57	63	67	41	40
XV.	100	98	86	105	43	57	62	72	39	42
XVI.	92	93	100	100	43	54	63	69	40	41
A.	99	97	101	98	48	63	65	71	42	44
C.	98	94	91	84	48	60	65	71	44	43
F.	104	105	94	89	51	66	67	75	45	44
Average	**97**	**96**	**96**	**94**	**46**	**60**	**64**	**71**	**42**	**43**
NEWTON WONDER.										
I.	97	98	83	76	57	60	71	74	47	47
X.	94	94	80	85	51	66	66	72	42	47
XII.	100	101	105	93	51	68	75	77	46	46
XIII.	93	88	88	90	54	63	69	73	43	42
XV.	95	100	80	92	46	63	67	76	40	44
XVI.	94	95	88	89	48	60	68	76	42	45
A.	95	97	91	92	51	60	70	72	44	47
C.	102	100	86	91	51	57	69	74	44	46
F.	108	110	77	79	57	66	73	80	46	46
Average	**98**	**98**	**87**	**88**	**51**	**63**	**70**	**75**	**44**	**46**

Appendix B.

Figures for Sets of Trees on each Variety of Stock separately, with Probable Errors.

Table a.—Average weight in oz. of Tree.

Allington on: Stock	Unit of Trees.	Clean.	Unit of Trees.	Feathered (minus feathers).
I.	(9)	**17.3**±.51	(7)	**22.6**± .73
X.	(10)	**14.2**±.68	(9)	**20.4**± .48
XII.	(10)	**17.0**±.85	(9)	**22.2**±1.08
XIII.	(11)	17.7±.63	(10)	20.0± .75
XV.	(9)	**15.1**±.44	(9)	**20.3**± .73
XVI. ..	(10)	**14.8**±.47	(9)	**19.0**± .89
A.	(10)	**17.2**±.55	(10)	**21.6**± .91
C.	(9)	**16.8**±.61	(9)	**21.0**±1.09
F.	(7)	**18.4**±.41	(7)	**23.4**± .67
Newton Wonder on: Stock				
I.	(9)	20.0±.79	(9)	20.9± .97
X.	(9)	**17.7**±.81	(9)	**22.8**± .68
XII.	(7)	20.3±.84	(7)	24.0± .87
XIII.	(9)	19.2±.74	(9)	21.6± .81
XV.	(9)	**16.4**±.90	(9)	**21.9**±1.06
XVI.	(10)	**17.2**±.74	(9)	**20.9**± .87
A.	(10)	18.3±.90	(9)	21.1±1.22
C.	(10)	17.5±.64	(10)	19.9± .59
F.	(9)	20.1±.82	(6)	22.7± .77

Table b.—Average Girth at "Collar" in mm.

Allington on : Stock	Unit of Trees.	Clean.	Unit of Trees.	Feathered.
I.	(9)	**64.0**± .93	(7)	**72.9**±1.54
X.	(10)	**60.6**±1.62	(9)	**69.7**±1.08
XII.	(10)	66.0±1.67	(9)	72.7±1.70
XIII.	(11)	63.3±1.23	(10)	66.9± .93
XV.	(9)	**62.2**± .78	(9)	**71.9**± .89
XVI.	(10)	**62.5**± .88	(9)	**68.6**±1.53
A.	(10)	**65.2**± .61	(10)	**70.8**±1.49
C.	(9)	**65.4**± .51	(9)	**70.9**±1.33
F.	(7)	**66.6**± .46	(7)	**74.0**±1.13
Newton Wonder on : Stock				
I.	(9)	71.1±1.05	(9)	74.3±1.37
X.	(9)	**66.2**± .92	(9)	**71.9**± .38
XII.	(7)	74.7± .82	(7)	77.3± .73
XIII.	(9)	69.2± .92	(9)	73.3±1.14
XV.	(9)	**66.8**±1.61	(9)	**76.1**±1.99
XVI.	(10)	**67.9**±1.03	(9)	**76.0**± .78
A.	(10)	70.2±1.53	(9)	72.4±1.66
C.	(10)	**68.5**± .93	(10)	**73.5**± .89
F.	(9)	**73.1**±1.29	(6)	**79.8**±1.36

Part II.

Physiology.

PRELIMINARY OBSERVATIONS ON THE CAUSES OF STOCK INFLUENCE IN APPLES.

By R. C. KNIGHT.

Observations upon the influence of rootstock on scion have been accumulating at this Station for some years, and it is now possible to predict with some confidence the type of tree which will result from any of a large number of combinations of stock and scion (1). So far, however, little progress has been made towards explaining the facts which have been observed. An explanation is manifestly desirable from every point of view, since elucidation of the principles involved would greatly assist further progress along practical lines, and moreover, would constitute an advance in our knowledge of physiology.

The physiological investigation of the problem of stock influence must of necessity be a slow and laborious process. Physiology is at present a youthful science, and as a natural consequence of this, physiological data are comparatively meagre. It is not possible, for instance, to find in the literature even a general account of the physiological characteristics of any plant or group of plants. It is therefore necessary, before beginning an investigation of such a specialised problem as that of the physiology of stock influence, to obtain some knowledge of the normal physiology of the plants concerned, and physiological research in this direction is thus likely to be slow.

Investigations are in progress dealing with the physiology of stock and scion and these will be reported when the results justify this. In addition, an attempt is being made to carry out, by means of field experiments, a preliminary analysis of the problem of stock influence. These experiments have reached a stage when it is possible to record the performance of the trees involved, although it must be emphasised that the results set forth below are of a preliminary nature and are not intended to indicate the stock-scion relations of mature trees. Records are being continued for a further period of years and will be reported at intervals.

A.—Root Influence and Stem Influence.

That portion of the tree which represents the stock consists of two main organs,—the root system itself, which performs the function of absorbing water and mineral substances from the soil, and a greater or less length of stem, which forms part of the path by which these materials are conducted to the scion. In trees which are budded or grafted near ground level, the length of this stem portion of the stock is small, but in trees which are worked at a higher level, the length may be considerable, and a "double-worked" or a

"top-worked" tree constitutes still another type. In any case the stem factor must be present in a worked tree, except in bench-grafts, which are uncommon.

It is not at all clear what part is played by the root-system and the piece of stem respectively, in the influence of the whole rootstock upon the scion. It is true that in this connection, more attention has been paid to the roots than to the stem, and this may indicate that the former are considered to be the more important factor. On the other hand, the traditional ideas concerning the double-working and top-working of certain varieties are evidence of the recognition that the stem portion of the plant may play a significant part in influencing the scion.

An experiment has accordingly been initiated to test the relative effect of the root portion and of the stem portion of the rootstock upon the scion. The plan was to propagate a series of trees in which the root system was that of a vigorous stock and a portion of the stem was that of a dwarfing stock, with some standard scion worked upon the latter. These were compared with a series of trees in which the root system was also that of a vigorous stock, and a portion of the stem was that of the same stock. Two unions were introduced between the roots and the scion in this second series in order to render the trees comparable with those of the former. Two other series were included with similar constitution except that the root system in these cases was that of a dwarfing stock. Broad-leaved English Paradise (Type I.) was used as the vigorous stock and Jaune de Metz (Type IX.) was used as the dwarfing stock, Lane's Prince Albert being the scion in all trees. The different forms of the series are shown in the diagram (Fig. 1).

The trees were obtained by the usual process of double-grafting. In Series A, for example, the stock, Type I., was whip-grafted as low as possible with a scion, also of Type I., and a year later this latter was again whip-grafted with a scion of Lane's Prince Albert. The length of the intermediate scion was about six inches. For the careful preparation of the trees in this and the following experiments, acknowledgment is due to Mr. A. W. Witt.

It will be evident that it is impossible, by means of trees constituted as in the diagram, to differentiate *completely* the influence of the roots and that of the stem of the rootstock, since a tree in Series B., for example, includes a short length of stem of Type I. (to which the roots are attached), as well as the length of the stem of Type IX., interpolated between the roots and the scion. The introduction of this short length of stem of the same character as the roots, although undesirable, appeared necessary for technical reasons. It would have been possible to bench-graft the Type IX. stem direct upon a piece of Type I. root, thus omitting the piece of Type I. stem altogether, but had this been done, there is no doubt that in many cases the intermediate piece of stem

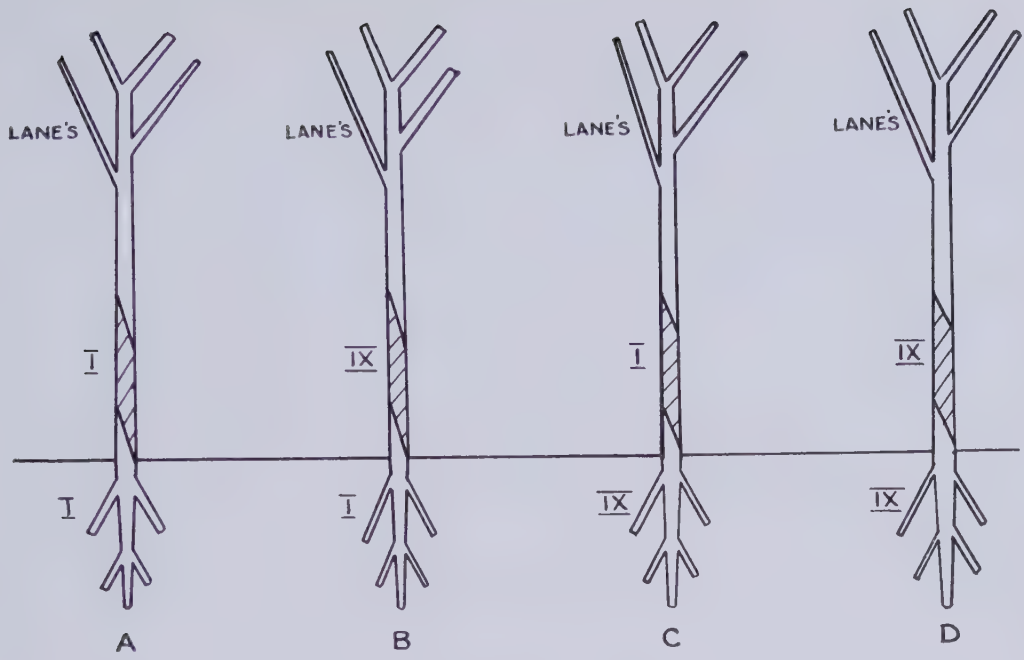


FIG. 1.
Diagram showing the constitution of the double-worked trees.

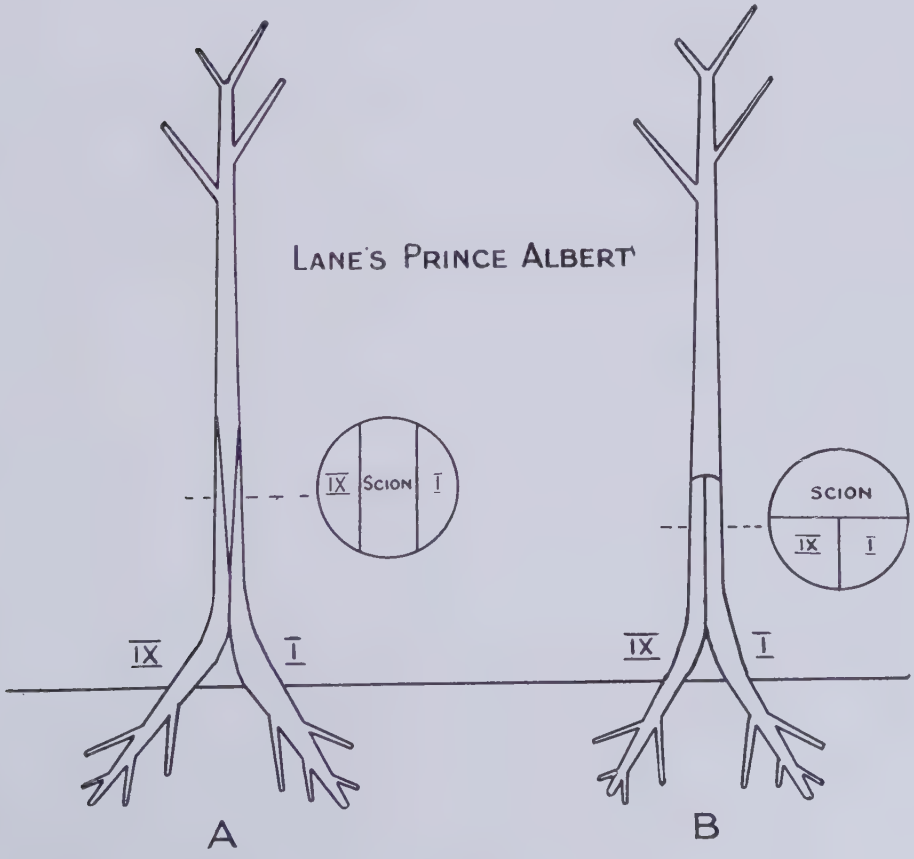


FIG. 2.
Diagram showing methods of grafting double-stock trees.

(Type IX. in Series B.) would have produced roots on being inserted below ground level, and the plant would then be supplied by a heterogeneous root system. Thus an unknown, and very variable factor would have been introduced into the experiment, and it was therefore considered preferable to introduce into Series B. and C. the constant, if undesirable, factor of the short piece of stem of the same nature as the root system.

The experiment is merely a variant of the double working experiment, in which a stem of a rootstock (the influence of which upon a scion is known), instead of a stem of a commercial variety, is used as an intermediate.

The trees were planted as maidens with 15 feet spacing, and were pruned to form ordinary bush trees. No fruit was allowed to develop during the first three years. The usual records of growth and bloom were taken, and these are summarised in Table I.

Each series consisted of six trees only and the figures given are the averages per tree.

TABLE I.

Average Length of New Growth and Number of Blossom Buds Formed on Double Worked Trees of Lane's Prince Albert.

Series. Root System. Intermediate.	A I. I.		B I. IX.		C IX. I.		D IX. IX.	
	Length of New Wood. cm.	No. of Blossom Buds Formed.	Length of New Wood. cm.	No of Blossom Buds Formed.	Length of New Wood. cm.	No. of Blossom Buds Formed.	Length of New Wood. cm.	No. of Blossom Buds Formed.
1923.. .. (Maidens)	95	0	100	0.5	60	2.2	51	2.2
1924.. ..	88	0.7	57	2.7	52	3.1	42	3.5
1925.. ..	184	5.8	98	11.2	99	19.8	81	20.6

It is seen from the Table that the introduction of a piece of stem of Type IX. between the roots of Type I. and the scion, as in Series B., considerably reduced the length of new growth as compared with that of the trees in Series A., except in the maiden year. On the other hand, the number of blossom buds formed has been very materially increased in each year by the presence of Type IX. as intermediate. A similar result is shown when the roots are of a dwarfing type. The replacement of the stem of Type IX. in Series D. by a stem of Type I. (as in series C) has had the effect of consistently increasing the length of new growth by some 20 per cent., whilst the number of blossom buds produced has been altered only slightly.

The results may also be expressed in terms of the number of blossom buds per metre of new stem produced in any one year. Other factors, such as the set of fruit, being equal, this figure may perhaps be taken as a better indication of the fruiting value of the tree than the mere number of blossom buds without reference to the vegetative growth. For example, a tree producing a large number of blossom buds may not be entirely desirable, if at the same time a disproportionate quantity of vegetative growth is produced, on account of the excessive space which the tree will occupy. Conversely the development of only a small number of blossom buds does not render a tree unprofitable if these are associated with relatively small vegetative extension. The ratio of blossom buds to the length of new stem is thus an approximate expression of the potential fruiting capacity with reference to the space occupied. Table II. shows this ratio for the trees under notice.

TABLE II.

Number of Blossom Buds per Metre of New Stem in Double Grafted Trees of Lane's Prince Albert.

Series	A.	B.	C.	D.
Root System ..	I.	I.	IX.	IX.
Intermediate ..	I.	IX.	I.	IX.
1923	0	0.5	3.6	4.3
1924	0.8	4.7	5.8	8.3
1925	3.2	11.4	20.1	25.5

These figures also show clearly that the fruiting capacity of the tree is considerably influenced by the nature of the intermediate piece of stem. The effect of the change of intermediate is here again much greater when the root system is vigorous than when it is dwarfing.

The figures in Tables I. and II. may also be regarded from another point of view. Although the change of intermediate from vigorous to dwarfing, as represented by Series A. and B., has increased the formation of blossom buds, it has done so at the expense of vegetative vigour. Thus the plants in Series B., instead of possessing, for example the vigour of a typical " Type I. tree," and the fruiting capacity of a " Type IX. tree," prove to be intermediate in both characters between the trees of Series A. and those of Series D. Similarly, whilst the trees of Series C. have greater vegetative vigour than those of Series D., they have at the same time slightly fewer blossom buds per tree, and considerably fewer per metre of new stem. Thus here again the trees exhibit an intermediate character and do not combine with their greater vigour the fruiting capacity of Series D.

It must be pointed out that there is a slight possibility that the differences in performance which have been recorded in the different series in this experiment may have been due in part to a factor other than the mere presence of the different intermediate stem pieces. In the course of the preparation of these trees, the conditions were not exactly identical for Series A. and B. During the season following the first grafting operation, each tree in Series A. consisted of a vigorous root system (Type I.) and a vigorous " first scion " (Type I.). Each tree in Series B., on the other hand, consisted of a vigorous root system (Type I.) and a dwarfing " first scion " (Type IX.). Thus for one season the root systems of Series A. were under the influence of vigorous scions, whilst those of Series B. were under the influence of dwarfing scions. It is known that a root system may be modified to some extent by the nature of the scion growing upon it, and therefore it cannot be assumed that the two series were comparable, as regards root systems, at the time of grafting the second scions. Thus some of the recorded differences between them may have resulted from differences in the respective root systems, arising during the season following the first graft. Similar remarks apply to Series C. and D.

There are however, two points which indicate that this initial difference of root system was not significantly effective. It would be expected from experience that after the final grafting of the same scion on all series, any differences due to initial quantitative differences in the roots would tend to become gradually obscured. Examination of the Tables reveals no such tendency over three seasons.

The recorded figures provide further evidence pointing in the same direction. The length of the maiden stems of Series B. was actually slightly greater than that of the stems of Series A., in spite of the fact that the intermediates in Series A. were Type I. and those in Series B. were Type IX. Subsequently, however, notwithstanding the initial advantage enjoyed by Series B., the trees of Series A. have produced in the following two years a greater length of new stem than those in Series B. This indicates that the fortuitous initial differences were counterbalanced in later years by the influence of the intermediate stem piece.

However, in view of the possibility of this error in the interpretation of the results, a further series of trees is in course of preparation, in which the difficulty of the influence of the first scion on the rootstock will be overcome by the use of " budded grafts."

In the present experiment, each series consisted of six trees only, and conclusions must therefore be regarded as only tentative. The results, however, indicate that whilst the root system of the stock is probably the dominating factor in the influence of stock upon scion, yet at the same time, the stem of the stock also plays a part which may be considerable.

B. Quantitative and Qualitative Factors.

The morphological expression of the influence of stock upon scion includes both quantitative and qualitative phenomena. For example, a scion worked upon a vigour-inducing stock, such as Type I, produces a more vegetative growth than the same variety worked upon a dwarfing stock such as Type IX. Further, in early life, the tree on Type IX. produces many more blossom buds than the tree on Type I. Thus there is in the two cases a different distribution of the growth activity, and a different type of growth results. There are also differences which are probably qualitative, as for example, the tendency of trees on Type V. to develop "leaf-scorch" (2).

It is reasonable to suppose that a quantitative difference such as that of vigour, may be due to a difference in the quantity of some nutrient substance supplied by the root system to the scion. On the other hand, it is conceivable that rootstocks may differ in their action as a result of qualitative differences in their protoplasm, which might involve, for example, qualitative differences in absorption from the soil, or metabolic differences.

It is a tradition in the practice of fruit culture that vegetative growth and reproductive growth are to a large extent antagonistic. That is to say that a tree which is in vigorous vegetative growth does not at the same time produce large numbers of blossom buds, and conversely, a tree which blooms profusely does not also undergo great vegetative extension.

It is perhaps a natural deduction from this view that restriction of vegetative growth will, in general, conduce to the formation of blossom. It is but a step further to the conclusion that the differences in the scion which are associated with stock influence, are due to quantitative differences between the rootstocks concerned. Thus a dwarfing stock may be supposed to induce profuse blossoming in the early life of the tree by reason of the fact that its root system remains smaller than that of a vigorous stock, and therefore supplied a smaller quantity of nutrient substances to the scion. The latter accordingly, can develop only a limited quantity of vegetative growth, and as a result of this a correspondingly greater quantity of blossom is produced. In this manner the size of the root system, acting indirectly through the medium of vegetative growth, may influence fruit production. Following this reasoning, it remains, of course, to explain the difference in the growth rates of the two root systems, but admitting the existence of the difference, the argument provides the outline of a possible explanation of stock influence.

There are, however, as mentioned above, points of difference in the behaviour of similar scions worked upon different stocks, which are not easy of explanation on the basis of a simple quantitative difference between the root systems. In view, however, of the possible importance of quantitative differences, an experiment is being carried out to investigate the question and

to determine, if possible, to what extent differences in scion performance are due to quantitative and to qualitative stock differences respectively.

In accordance with the reasoning which has just been put forward, it appears that if a tree with a vigorous rootstock could be so constituted that the normal supply of root-absorbed nutrients to the scion were reduced, then the scion should act in a manner normally associated with the influence of a less vigorous stock. In other words, if a root system of Type I. supplied its scion with a subnormal quantity of nutrients, the resulting tree should produce less vegetative growth and more bloom than the normal Type I. tree.

An attempt was accordingly made to modify the root-scion relations in this manner by cultural methods. A series of trees was prepared in which the stock, instead of being budded normally, was budded with three separate buds of the scion, placed as near the same level as possible but on different sides of the stem. Each bud was treated in the manner normal to the ordinary single bud which is worked on a stock. In some instances, one of the three buds failed to grow, so that some of the resulting trees consisted at the outset of two branches, and some of three branches growing upon one rootstock. It was postulated that in a tree constituted thus, the supply of nutrients from the roots would have to be distributed among two or three separate scions, which by their behaviour would show whether this change of quantitative relations produced results comparable to those effected by a change of stock.

It was expected that if any such change of behaviour was noticed as the result of the multiple budding procedure, it would tend to become obscured after the early years. The tree might be considered as consisting at first of a preponderance of scion and a normal amount of root system, but it was recognised that such a condition is unstable and there would be a tendency to readjust the equilibrium towards the normal. On the other hand there is a possibility that the abnormal condition at the outset might produce some more permanent physiological disturbance which would impress itself upon the older tree also.

In 1921 a preliminary experiment was commenced in which some large five-year-old stocks of Types V. and IX. were multiple-grafted with Lane's Prince Albert. The number of trees in a batch was only three, and the stocks were unsuitable for the purpose ; they were, however, the only ones available at the time. Records were taken for three years on these trees to obtain preliminary results whilst a more suitable series was prepared. The results obtained from these first grafted trees were exactly similar to those which have been recorded in the later experiment, so in view of the foregoing considerations, only the later results on the more suitable series of trees will be given.

In the latter case, two-year stocks of Types I. and IX. were triple budded with Lane's Prince Albert, and other batches of similar stocks were budded

normally with the same variety, as controls. Each batch consisted of six or seven trees which were planted with 15 feet spacing and treated as were those in section A above. The usual records were taken and the figures obtained to date are given in Tables III. and IV.

TABLE III.

Length of Stems and Number of Blossom Buds formed in Single- and Multiple-Budded Trees of Lane's Prince Albert on Types I. and IX.

Series ..	A.		B.		C.		D.	
Stock ..	I.		I.		IX.		IX.	
Average No. of Scions per Tree.	1		2.4		1		2.6	
	Length of New Wood. Cm.	No. of Blossom Buds Formed.	Length of New Wood. cm.	No. of Blossom Buds Formed.	Length of New Wood. cm.	No. of Blossom Buds Formed.	Length of New Wood. cm.	No. of Blossom Buds Formed.
1923.. .. (Maidens)	97	0	80	0.5	112	4.5	68	6.9
1924.. ..	101	1.7	69	1.5	81	5.2	45	5.7
1925.. ..	254	4.7	161	3.1	179	22.7	99	24.2

The figures in Table III. are expressed as the averages *per scion*. The trees of Series B. and D., carrying more than twice as many scions as those of Series A. and C. respectively, consistently produced a greater length of growth *per tree*, as was expected and intended, but individual scions in the multiple-budded trees produced less vegetative growth than those in the single-budded trees. In the case of blossom bud formation, it is noteworthy that some scions in Series B. began blooming a year earlier than any in Series A., indicating an approach, on the part of Series B., towards the Type IX. class of growth. In the second year, however, the scions in Series A. showed more bloom than those of Series B. and increased their superiority in the third season. The trees on Type IX. show a similar tendency, the blossom bud-formation in Series C. gradually approaching that in Series D., although in this case it is doubtful whether the differences involved are significant.

Table IV. gives the ratio of number of blossom buds to length of new growth, and in this case of course, the number of scions per tree does not enter into the calculation.

This method of expressing the results also demonstrates the apparent tendency of Series B. to revert to the normal Type I. class of growth shown by Series A. This tendency is not yet shown by the multiple-budded trees

TABLE IV.

No. of Blossom Buds per Metre of New Stem in Single- and Multiple-Budded Trees of Lane's Prince Albert on Types I. and IX.

Series	A.	B.	C.	D.
Stock	I.	I.	IX.	IX.
Average No. of Scions per Tree	1	2.4	1	2.6
1923	0	0.6	4.0	10.2
1924	1.7	2.2	6.4	12.7
1925	1.8	1.9	12.7	24.6

on Type IX. This last distinction was also shown by the records for the Type IX. trees in the earlier multiple-grafted series.

It is seen from Table III. that the vegetative vigour of the scions of Type I. is much decreased by multiple-budding. The value is below even that of the normal scions on Type IX. in each of the three years. In the case of the scions on Type IX., multiple-budding has also reduced the length of new growth, the relations between the two series being shown in Table V.

TABLE V.

New Growth of Multiple-Budded Trees as Percentage of that of Normal Trees.

Year.	$\frac{B.}{A.} \times 100$ (Type I.)	$\frac{D.}{C.} \times 100$ (Type IX.)
1923	83	61
1924	68	56
1925	63	55

The difference in vegetative growth is quite considerable and does not decrease during the first three years. The development of fruit might have been held responsible for the maintenance of these vegetative differences, but no fruit has been allowed to set. The differences in the quantity of blossom borne appear to have been too small to be effective, and have not always been in the same direction, so that the vegetative differences were apparently due to different stock-scion relationships produced by the different constitution of the trees.

Although such marked differences have been produced in the vegetative growth, no corresponding influence has been exerted on blossom production. Series B., in spite of multiple-budding, has produced less blossom buds per

scion than Series A. (5.1 against 6.4 in three years). When Type IX. is the stock, a small difference appears in favour of the multiple-budded trees (36.8 against 32.4).

A single experiment extending over such a short period, does not justify the far-reaching conclusion that in stock-scion relations, whilst quantitative stock-factors influence vegetative growth, reproductive growth is governed by qualitative considerations. There is indication, however, that although some effect has been produced on vigour by the quantitative change in the form of the tree, this agency has not produced any change in reproductive growth which is at all comparable to that which can be produced by a change of stock.

C. The Blending of Stock Characters.

Combination by sexual propagation of desirable characters inherent in different varieties is an every-day method of the plant breeder. It was thought that possibly some such combination might be achieved by purely vegetative means. Thus if two stocks, one inducing vigour and another early fruiting, could be incorporated with a scion into a single tree, the scion might exhibit both vigour and precocity, and develop into a large tree bearing fruit in its early years; the economic value of such a tree is obvious. At the same time the behaviour of such a tree might be expected to provide some information concerning stock-scion relations. If the physiological difference between a vigorous, late fruiting and a dwarfing, precocious stock is mainly a difference in relative quantities of nutrient materials which they respectively supply to the scion, it appears reasonable to expect that in a composite tree including two such stocks, the characters of the two would be blended and the scion would exhibit intermediate characters. On the other hand, if the difference between the stocks involves a qualitative difference, such as that between the presence and absence of a substance, in the supply of material to the scions, then in the composite tree the character of one stock might be expected to be superimposed upon that of the other. Thus the scion would combine some of the characters of the two stocks without quantitative change. In this event a combination of a vigorous, late-fruiting and a dwarfing precocious stock could result in a vigorous, early fruiting tree or conversely a dwarf tree, sterile in its early years.

Such a suggestion is distinctively speculative, but the state of our knowledge of the problem provides practically no working basis, and this fact must be held to justify long-range speculation in devising preliminary experiments.

Since 1922 several series of trees have been grown in which two stocks and one scion were combined. Three distinct methods of propagation have been tried, as follows:—

1. Two stocks were planted about eighteen inches apart, the stems leaning towards each other at angles of about 45°, with the horizontal. A year later a

scion was whip-grafted to one of the stocks in the normal manner and the apex of this scion was whip-grafted to the other stock of the pair, thus forming a hoop. One bud of the scion was allowed to develop and was treated in the manner normal to a grafted plant. The method proved unsatisfactory because a proportion of scions failed to make satisfactory unions at the distal end, and even when a good union was effected at this point, the stock in many cases soon died; this fact is interesting in showing the pronounced polarity of the graft. Furthermore, this polarity necessitated the use of a double number of individuals in order to control differences arising from the fact that one stock of a pair was attached to the proximal and the other to the distal end of the scion.

2. Two stocks were planted about six inches apart at such angles as to make inarching easy. A year later the stocks were cut back to within a foot of the ground and pared as if for inarching. A scion, pared as for a wedge graft, was placed between the upper ends of the prepared surfaces of the two stocks, and the three individuals were bound together and waxed. This process may be described as inarching and grafting in one operation. The stocks for such trees were planted at the outset in their permanent positions, and the trees were not moved after grafting. The form of the tree is shown in Figure 2.

3. This method was a variant of the previous one and the pairs of stocks were planted in the same manner. In this case, the stocks were inarched in a normal manner and were allowed to grow thus for a season. Following this, the united stocks were cut back to the region of the union, and a scion was whip-grafted to this region, the plane of the union between scion and stocks being at right angles to the plane of union between the individual stocks, the scion being applied as symmetrically as possible to the stocks. The form of the tree is shown in Fig. 2B.

Four series of trees are under observation, two series of which were propagated by method 2 and two by method 3. The scion used has been Lane's Prince Albert, and this has been grafted to each of four different combinations of stocks, comprising twenty-nine trees. The pairs of stocks were as follows :—

Group.	Vigorous.	Semi-Dwarfing.	Dwarfing.
A.	I. and I.		
B.	I. and		IX.
C.		II. and	IX.
D.			IX. and IX.

Each combination was included in at least two of the four series.

A summary of the results is given in Table VI., the figures representing the averages per tree for the first three years.

TABLE VI.

Length of New Stems and Number of Blossom Buds of Lane's Prince Albert on Double Stocks. Average per tree over three years.

Group .. .. Stocks	A. I. I.	B. I. IX.	C. II. IX.	D. IX. IX.
Length of new Stems cm. ..	705	584	496	390
As per cent. of Group D. ..	181	150	127	100
No. of Blossom Buds	8.8	10.4	25.4	53.6
As per cent. of Group D. ..	16	19	47	100
Blossom Buds per Metre of new Stem	1.25	1.8	5.1	13.7

These results are very clear-cut and show that some of the stock characters are blended in an even manner. The presence of the dwarfing stock in Group B. has decreased the length of wood growth by 17 per cent. and increased the number of blossom buds by 18 per cent. as compared with Group A. Comparing Groups B. and C. with D., the presence of Type II. instead of Type IX. has increased wood growth by 27 per cent., whilst the presence of Type I. produced an increase of 50 per cent. The blossom buds in Group C. amount only to 47 per cent. of those in Group D., whilst in Group B., although a precocious stock (IX.) is present, the number is reduced to 19 per cent. of those in Group D.

Unfortunately no single-stock trees are available which have been treated in the manner described for those under consideration, but it may be of interest to record approximate figures for wood growth over the first three years of trees of Lane's Prince Albert on single stocks, which were transplanted from the Nursery as maidens.

Type XII. (Very vigorous.)	Type I. (Vigorous.)	Type II. (Semi-Dwarfing.)	Type IX. (Dwarfing.)
640 cm.	550 cm.	440 cm.	360 cm.

These are not strictly comparable with the figures in Table VI. on account of the check due to transplanting, but they are of interest in indicating the normal range of vigour of the variety.

The double stock trees in Group A. were more vigorous than the single stock trees on Type I. but it is impossible to say to what extent this is due to the extra root system present, and how much to the root system having been left undisturbed. Similar remarks apply to comparisons of other groups.

The figures for wood growth in Table VI. constitute an evenly graded series in which Group B. (584) is not far from the mean of Groups A. and D. (548), and

this indicates an even blending of the normal influences of the two stocks. There is no indication of any considerable dominance of the invigorating influence of one stock over the dwarfing capacity of the other. In the case of blossom buds, however, Group B. is very similar to Group A. and quite unlike Group D. In this case it would appear as if the late fruiting tendency of Type I. had dominated the precocity of Type IX. It is not at all clear however, to what extent the difference of vigour influenced blossom formation.

Since the factors influencing vigour can be thus combined by vegetative means, it appears likely that they are physiologically of a quantitative nature, but judgment concerning blossom bud formation must be suspended. A further series of trees with larger units is being prepared in order to repeat and extend the observations.

Summary.

Three years' results are recorded from preliminary experiments designed as a first analysis, by field methods, of the nature of stock influence.

A " double-working " experiment, using stems of stocks as intermediate scions, indicates that the stem as well as the root system of a rootstock may play a considerable part in influencing the scion.

The behaviour of " multiple-budded " and " double-stock " trees in their early years suggests that purely quantitative differences between stocks play a part in producing scion differences.

The vegetative union of a scion with two stocks of different character produces a tree the vigour of which is intermediate in type. The factors coming from the stock which govern blossom formation do not appear to be evenly blended.

References.

(1) *Hatton, R. G.* The Influence of Rootstock upon the Tree Fruits. Fruit Grower, 1923, 16, 639-641, 699-700, 759-760.

(2) *Hatton, R. G., and Grubb, N. H.* Field Observations on the Incidence of Leaf Scorch upon the Apple. J. Pom. and Hort. Sci., 1925, 4, 65-77.

THE RELATION IN THE APPLE BETWEEN THE DEVELOPMENT OF YOUNG SHOOTS AND THE THICKENING OF OLDER STEMS.*

By R. C. KNIGHT.

In the course of an examination of some anatomical features of young stems of the apple at different seasons of the year, it was observed that in spring the new xylem which was being formed was often distributed irregularly over the length of the stem. At some levels a considerable extension of girth had taken place, whilst at the same period, other regions of the same stem showed little or no sign of new wood. Frequently, also, the new tissue was not evenly distributed at any one level, but was very much more extensive on one side than on the other. Later in the season these irregularities ceased to be so obvious and, apart from its natural taper, the stem appeared to be fairly evenly thickened throughout its length. As a result of this observation, a large number of apple stems have been examined at different stages of growth and some facts have been observed which throw light on certain growth responses to pruning which have been reported from experiments in the field.

The phenomena observed may be summarised in the statement that when dormant buds break into new growth in the spring, the new xylem appears first in regions bearing such developing buds. Thickening of regions of the stem which do not carry active buds begins only at a later stage, spreading progressively from the vicinity of the new shoots. During the normal development of a one-year-old unpruned shoot, the apical bud is the first to begin growth and it is followed by the lateral buds close below it. The apical bud usually forms the strongest shoot and the lateral shoots are progressively weaker the farther they are from the apex, until, when the lower end of the stem is reached, the buds either form very short leafy " spurs " or remain entirely dormant. When this type of growth occurs, new thickening begins immediately below each of the growing new shoots and spreads downwards to the " bare " regions of the stem. Thus by the time thickening has just begun in the portion of the stem bearing no secondary shoots, the upper region near the new shoots shows several layers of new xylem elements. The process is most obvious in the stems of varieties which normally produce considerable lengths of " bare wood," that is, varieties in which many buds remain dormant.

When a large number of the upper buds break into active growth each contributes its share towards thickening the stem and the circumstances are also

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complicated by the presence of spurs. The process can, however, be very much simplified by removing during the dormant season all buds from a stem except one or two near the apex. When these buds have produced shoots a few centimetres in length, the progressive decrease in the amount of new thickening from apex to base can easily be seen. The details of such a shoot are shown in Plate I. All the buds except two close to the apex were removed from the shoot in the winter, and on June 1st, the stem was sectioned at various levels as indicated in the fig 1. The sections (fig. 2 A—C) show the extent of the new xylem at points denoted by the lettering. At A, just below the new shoots, a large mass of new tissue has already been added, whilst at B, there is a smaller increase. At C, some 25 nodes from the apex, only one or two rows of new wood have been added, and the decrease is found to be progressive throughout the shoot. About the middle of May, such a shoot shows the thickening just begun near the apex, whilst lower down the stem no new xylem at all is visible.

With some varieties it frequently happens that a few buds near the apex develop into new shoots whilst several buds below remain dormant, and still further down the stem, one, or perhaps two buds grow into fairly strong shoots and below these again no new laterals develop; such a shoot as this shows very clearly the association of new thickening with the growing shoots. Near its apex, considerable thickening occurs; the extent of the new tissue decreases with increasing distance from the apex until the lower developing laterals are reached, when more new wood is visible, and this decreases again when the lower dormant buds are reached.

In the region of a strong lateral shoot the greatest quantity of new wood is found not only at the same level as the new shoot but also on the same side of the parent stem. Thus in early June, the new thickening forms a crescent on one side of the old xylem, and if more than one lateral shoot is present, a corresponding number of crescents of new wood may be found. Plate 2 shows the development of a shoot "disbudded" in order to produce such crescents. In this case, about six inches of the apex of the stem was removed in winter and the uppermost remaining bud was left to develop. The next twelve buds were removed while the fourteenth and fifteenth were untouched. Below these again all buds were removed. Thus a strong shoot developed from the uppermost bud, which was actually a lateral, and shoots also developed from the fourteenth and fifteenth buds. On June 1st, a large crescent of new wood had developed in the internode below the top shoot (fig 4A). The size of this crescent decreased at lower levels until the fourteenth bud was reached (fig 4B), and below the fifteenth bud a second small crescent of new elements appeared (fig 4C). It is probable that the larger crescent in C includes some wood associated with the shoot of bud fourteen as well as that associated with the uppermost shoot. Below these shoots a further decrease in new wood was observed.

It is significant that the section fig. 4B, immediately above the shoots fourteen and fifteen, shows no sign of the small crescent which is visible in C. This denotes that whilst the thickening has spread downwards from these shoots, it had not, at this stage, spread very far upwards. The distribution of new thickening in relation to the new shoot at a later stage is shown by some figures obtained on June 21st from a shoot the upper and lower buds of which were removed when dormant. One bud only, about 30 cm. from the apex, was allowed to grow and when this bud had produced a shoot 20 cm. long, sections of the parent stem were cut at points 1 cm. above and 1 cm. below the new shoot. These sections were drawn in outline with a projection ocular and the areas of the cross section of the new and the old wood were measured with a planimeter. The results were as follows :—

	Cross sectional Area (cm. ^{2}) of :		%
	1925 Wood.	1926 Wood.	Increase
Above new shoot	0.086	0.014	17
Below new shoot	0.110	0.060	55

It is quite clear from this that although thickening had begun at a point 1 cm. above the new shoot, both the actual and the relative extent of this thickening was much less than the increase in size at a point the same distance below the shoot.

Although small masses of new xylem arise in the stem near the base of the bud practically simultaneously with the commencement of growth by the latter, there appears to be no doubt as to the physiological sequence of the two phenomena. Following the development of an upper bud, new xylem soon appears very close to dormant buds immediately below, but these do not respond by breaking into growth. On the other hand, wherever bud-growth occurs, new xylem formation invariably accompanies it. This indicates that the new wood is laid down as a result of bud development and that the latter process is not a consequence of the proximity of new thickening.

The process of the development of new thickening appears thus to be dependent upon some products of young growing shoots. The region nearest these shoots, owing to its position, is most favourably situated for obtaining these products and it is the first to begin to expand. It is only when the requirements of this portion of the stem are provided for, that supplies are available for other regions. Further, the tissues directly below a shoot are more readily supplied than those above, and even the lower portions of the parent stem which are not vertically below the new shoot, receive their first supplies relatively late. The whole process may be visualised as a wave flowing along a course vertically downwards, but overflowing laterally and upwards as its volume increases.

The physiological processes involved in the lignification of cells formed on the inner side of the vascular cambium are of a distinct character. Lignification of a cell involves the death of the protoplast and addition of material to the cell walls. The substance of the protoplast disappears, presumably as the result of catabolic activity, and in consequence, nitrogenous substances must be produced and are probably available for re-synthesis by adjacent living cells. The increase in thickness of the cell walls utilises large quantities of materials of carbohydrate nature, such as are being manufactured in the new leaves. It appears therefore, that the formation of new wood elements, involving the release of nitrogenous substances and the consumption of carbohydrates, is closely associated with, and dependent upon the development of young leafy shoots on account of the carbohydrates which the new shoots supply.

In experiments upon root formation by stem cuttings, van der Lek (2) found that in some circumstances the amount of root production was largely determined by the development of the leaf buds, and he is of the opinion that the growing bud produces a substance of the nature of a hormone which stimulates root growth. It is possible that the phenomena described above may be explained in a similar manner, and it may be urged that the process of lignification does not depend upon new shoots for a supply of carbohydrates, but that on the contrary, these substances are available in the form of starch stored in the stem. Furthermore, the process of stem-thickening is not merely one of lignification, for it also involves the activity of the cambium for the production of new cells, the lignification of which is merely an after effect; it is not clear how cell division in the cambium could be induced by the presence of carbohydrate supplies formed by new leafy shoots. It is possible that stimulation by a hormone and the availability of carbohydrates are complementary in their influence on the process of new xylem production.

The association of the growth of new shoots with the formation of new xylem in the parent stem has a direct bearing on the effect upon subsequent growth of the removal of lateral shoots from young trees. Results of experiments bearing on this question are reported by Hatton and Amos (1). They found that if lateral shoots as they appeared were removed from the stems of a young tree, there was a very definite effect upon the growth of the tree in the course of the season. This effect appeared to be graded, and increased from above downwards. The size of the head of the tree was unaltered by the pruning treatment, whilst only a slight effect was observed on the stem-girth two feet from the ground. The girth at the base of the stem, however, was reduced by some 10 per cent. by the removal of the laterals, whilst the weight of the roots was very much less in the " defeathered " trees than in the untreated series. These results can be explained in terms of the facts concerning new thickening and new stem growth recorded in the present paper. Since the

thickening of a stem begins in the region of buds which are developing into new shoots and spreads downwards from these, it is evident that increase in size of the base of a stem from which growing shoots are removed, will not begin so early in the season as that of the base of a stem carrying its normal laterals. In the former case the base of the stem is much further from developing new shoots than in the latter, and the downward spread of the thickening takes longer to reach the base. Consequently, the lower portion of the stem free from laterals is expanding during a shorter period than the base of a normally " feathered " stem ; the result is a greater total thickening of the latter.

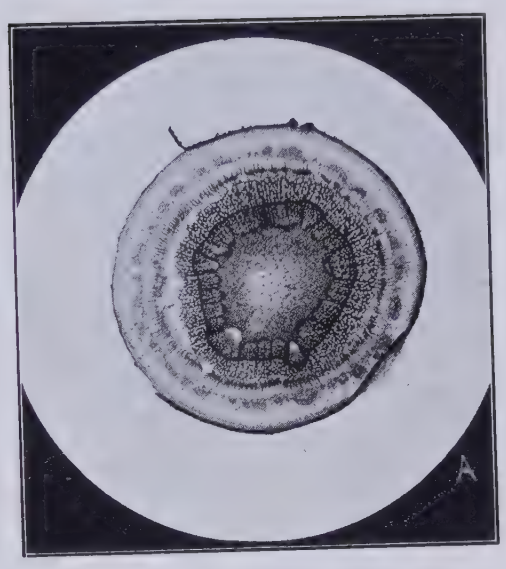
The influence of lateral pruning upon the girth of the stem at the two-foot level can also be correlated with the facts in the present paper. Information kindly supplied by the authors referred to, indicates that the laterals appearing on the stem below the two-foot level were both more numerous and more vigorous than those growing above. Since the spread of the thickening is primarily downwards and only secondarily upwards, it is to be expected that the girth at two feet is chiefly influenced by the laterals above that level ; these were few, and the resulting difference in girth was less marked at that point than near the base. This reasoning is also capable of extension to the head of the tree, which, being above all the stem-laterals, is uninfluenced by their removal.

The question of the effect of the removal of laterals on root development is really beyond the scope of this paper, but the mechanism producing the effect is apparently similar to that under discussion. Carbohydrate materials for root-formation must come from the leaves, and the effect of preventing the growth of laterals is, in effect, to remove the source of new carbohydrate supply farther from the roots. It is reasonable to suppose that the carbohydrates are more readily available at points near the source of supply than in regions farther removed. Consequently, the downward gradation of the thickening process is probably continuous, and expansion of the roots will begin still later than girth-increase at the base of the stem. Similarly if the extension of the root-system is dependent upon a hormone formed during stem growth, as van der Lek suggests, lateral pruning delays the arrival of the hormone at the root meristems and the commencement of growth is postponed.

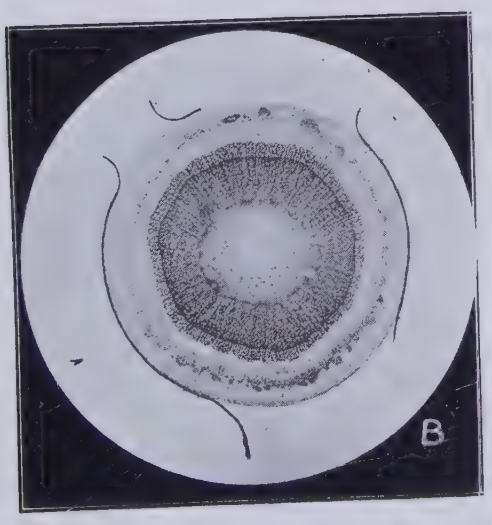
Thus the effect of the pruning treatment upon the season's root-increase will be more marked than the effect upon the stem expansion. It is perhaps significant that the presence of laterals on the stem appears to affect the root development chiefly by increasing the thickness of individual roots, as indicated in Table II. of the paper by Hatton and Amos. This affords additional evidence of the continuous nature of the downward spread of the commencement of new thickening not only from one region of the stem to another, but also from stem to roots.

PLATE I.

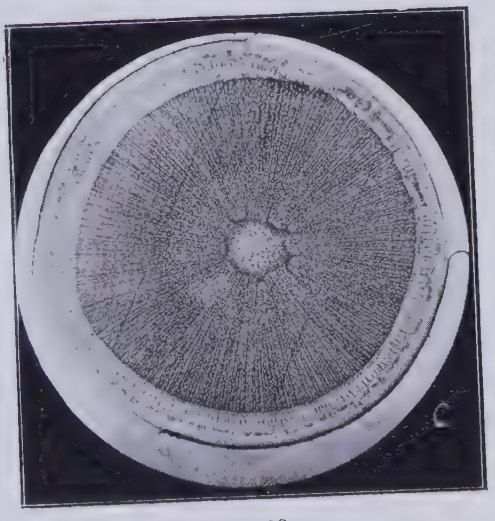
1.



2A.



2B

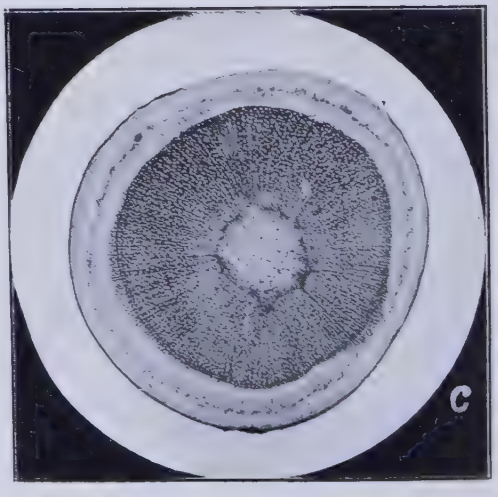


2C.

3.

4A

4B



4C

Summary.

In Spring new wood formation in the stem of the apple begins in close proximity to a developing shoot and spreads vertically downwards. Upward and lateral spread of such thickening occurs only later.

These facts throw light on the growth responses to certain pruning operations.

Explanation of Plates.

Plate I. Distribution of new thickening of apple stem when only upper buds develop.

Fig. 1. Shoot showing positions at which sections 2 A—C were cut.

Figs. 2 A—C. Sections cut at levels A, B, C of Fig. 1.

Plate II. Distribution of new thickening of apple stems when lateral buds develop.

Fig. 3. Shoot showing positions at which sections 3 A—C were cut.

Figs. 4 A—C. Sections cut at levels A, B, C of Fig. 3.

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(2) *Van der Lek, H. A. A.* Over de Wortelvorming van Houtige Stekken. Meded. v. d. Landbouwhoogeschool te Wageningen, 1925, 28, 1-230.

OBSERVATIONS ON THE WATER CONDUCTIVITY OF THE STEMS OF REVERTED BLACK CURRANTS.

By R. C. KNIGHT.

The work of Farmer* suggested the possible importance in the economy of the plant, of the resistance offered by the water channels to the flow of liquid. Supplementary to the general study of reversion (a progress report of which appears in the present volume) which is being carried out at the Station, a comparison has been made, in a small series of experiments, of the water conductivity of the stems of normal and reverted plants.

The apparatus was essentially of the same design as that used by Farmer. Water from the main supply was passed through a cotton-wool filter to remove any solid particles likely to cause obstructions in the stem, and was then led through a T-tube dipping into a column of mercury, by means of which the pressure of the supply to the stems could be prevented from rising beyond any selected level. From the T-tube the water passed through a main supply tube provided with side branches, to which were attached the stems to be investigated. The pressure was read from a mercury manometer, attached to which was an electrical device which gave audible warning when, owing to occasional fluctuations in the main water supply, the pressure in the supply tube fell below the selected level. This was necessary since it is impossible to watch the manometer continuously, owing to other experimental operations, and a fall of pressure for a short time naturally vitiates the experiment.

During any one experiment both normal and reverted shoots were always treated simultaneously. Shoots of the previous year's growth and of similar size were selected, the experiments being carried out during the dormant season. The apical 15 cms. of each shoot were removed and the next section of 30 cms. was divided equally into two lengths, the upper length being termed for convenience "apical," and the lower "basal." All shoots before being used were immersed in boiled water in a bottle, which was then evacuated. The pressure was released after fifteen minutes and the process repeated two or three times. After this treatment the cut ends of the lengths of stem were never allowed to dry. Each length was attached by its basal end to the apparatus by means of pressure tubing, which was not wired on unless leaks actually developed, in order to avoid any compression effect on the stem. The pressure throughout was maintained at 30 cms. of mercury at the points of the entry of the water into the stems. The liquid emerging from each stem was led to a tube with a square cut

* Farmer, J. B. On the Quantitative Difference in the Water Conductivity of Wood in Trees and Shrubs. Proc. Roy. Soc., 1918, 90B., 218-250.

end, from which it dropped into a collecting vessel. The time required for each successive drop to form and discharge was recorded and the average weight per drop was determined by weighing the liquid collected. By this means, several successive readings over short periods were obtained from each length of stem. It was usually found that the rate of flow was slightly higher after five or ten minutes than immediately after the pressure was applied. This may have been due to initial internal absorption or to slowness of the adjustment of internal pressures. After the first ten minutes the rate of flow either remained constant or decreased very gradually. In all cases the highest rate measured was taken to represent the conductivity.

Thick transverse sections were then cut of the two ends and of the middle of each length of stem. They were drawn in outline with a camera lucida and the wood area measured by a planimeter. The average area of the wood in these three sections was regarded as the average for the whole length of stem. The conductivity was expressed as the weight of liquid passing per hour through 15 cms. of shoot with wood of an average cross section of 1 square centimetre.

In spite of the apparent uniformity of the material the results showed very considerable variation from shoot to shoot, and this is entirely in accordance with the variability found by Farmer in deciduous trees. The conductivity of normal shoots varied from 21 to 67, and that of reverted shoots from 29 to 69. As Farmer points out, it is probable that the material is actually very variable owing to differences of cultural conditions and therefore the calculation of arithmetic means and probable errors is of doubtful value unless large numbers of individuals are taken. Presentation of these will, however, obviate the necessity of giving details.

Conductivity of Black Currant Shoots, 15 cms. long.

Gms. per hour per cm.² cross section.

Averages of 21 shoots.

Normal.	Reverted.
48.3±1.6	48.8±1.7

There is apparently, therefore, no difference in the water conductivity of stems of normal and reverted black currant bushes and the physiological differences which give rise to the characteristic morphological differences must be sought elsewhere. Differences in the conductivity of "apical" and "basal" lengths of stem amounted to 13 per cent., but as the probable error was approximately half of this, it is hardly significant.

Negative results must frequently occur in such instances as the present when practically nothing is known of the fundamental physiology of the plant involved, but they serve a useful purpose in excluding certain circumstances as

possible factors in the phenomena concerned, and in addition they add a little to the knowledge of varietal physiology.

The result obtained is also interesting in view of the anatomical study of reverted black currants, recorded by Ridler.* Some reduction was found in the amount of wood in reverted as compared with normal stems, but the opinion is expressed that such differences as were observed were insufficient to account for the large morphological differences.

* Ridler, W. F. F. "Investigation of the Structure of Black Currants." Ann. Appl. Biol., 1924. II. 252-260.

Part III.

Pathology.

NOTES ON PLANT DISEASES IN 1925.

By H. WORMALD.

The year 1925 as a whole was characterised by two long periods of generally wet weather with a comparatively dry period between them, and these weather conditions were reflected in the varying incidence of plant diseases. The earlier months of the growing season were marked by the prevalence of (among other diseases) apple mildew (*Podosphæra leucotricha*) and apple scab (*Venturia inæqualis*. Owing to the hot dry weeks which succeeded, in June, potato blight did not appear so early as in 1924, but the wet weather which was experienced towards the end of summer was responsible for the rapid spread of the blight and for much damage caused by rot-producing fungi such as *Sclerotinia fructigena* and *Botrytis cinerea*.

The incidence of diseases not caused by parasites, but which were probably, in most cases, a result of the sudden changes in temperature and humidity, was a feature of the season. One of the most serious of these diseases was the dying out of young fruit trees. During July cases were brought to my notice of pear, plum and apple trees dying in alarming numbers without any apparent reason, as the trouble could not be traced to any parasite. The probable explanation is that the cold wet soil checked root development during the winter and spring to such an extent that, with the advent of a spell of dry weather in early summer, the trees on certain types of soils were unable to adjust themselves to it. This was undoubtedly the reason of the failure in certain instances of young trees planted up during the winter of 1924-5 ; some of these when examined in July had made little or no root growth.

Certain " functional diseases " of apples were also common in the autumn e.g., Bitter Pit and Glassiness (or Water Core) ; the cause of these two diseases is obscure but they are generally attributed to sudden fluctuations of sap pressure within the tree as a result of changes in the weather. A form of Internal Breakdown resulting in ill-defined brownish blotches, which gradually spread over the fruit, was also prevalent on certain varieties in November and December soon after they had been stored. These discoloured areas are easily bruised and cracks arise so that soft rot fungi get in and complete the damage ; apples so affected are not only themselves destroyed, but when bearing a crop of fungal fructifications they become a menace to other apples in the vicinity. This disease was responsible for considerable loss on the Station in the varieties Bramley's Seedling, and Lane's Prince Albert (particularly the latter) during November. That the trouble was not purely a local one was shown by the fact that specimens showing the same " breakdown " were received from several

other localities. This disease is one that sometimes appears on apples kept in cold storage* (Bramley's Seedling is particularly susceptible to this form of injury in cold store) and it is suggested that the low temperature, exceptional for the time of the year about the time of picking the fruit, was the chief factor responsible for this condition of the apples.

On cherry trees a condition sometimes referred to by the growers as " rust " appeared in at least two localities, from which specimens were received. This " rust " appears on the one year old twigs ; the bark becomes ruptured exposing a rust-like powder which on microscopic examination is seen to consist of collapsed dry rectangular cells that readily separate from one another. This condition again is not, so far as is known, caused by a parasite ; it is probably a result of the weather conditions obtaining about that time. The specimens were received towards the end of July during a period of heavy rains following a drought. The variety Early Rivers appears to be particularly subject to this disease. One grower who sent specimens wrote, " It is only on the Early Rivers that the rust-like powder shows itself. It seems to be the only sort attacked out of roughly twenty sorts grown in the same quarter."

Several diseases, which so far as can be ascertained have not previously been recorded for Britain, came to my notice during the year. These, together with the organisms associated with the diseases, are as follows :—

A Leaf Blotch of Quince Trees (*Sclerotinia cydoniæ*). See page 87.

A Leaf Disease of the Shasta Daisy (*Septoria leucanthemi*). See page 96.

A Leaf Disease of *Elæagnus pungens variegata* (*Phyllosticta argyræa*). See page 84.

A Bacterial Leaf Spot of Walnut (*Pseudomonas juglandis*). See page 85.

Though these diseases were not causing any great injury they present certain features of interest and therefore will be dealt with a little more fully on the pages indicated.

There is evidence that at least one of these diseases (the one on the Shasta Daisy) has been known in this country for several years, although not put on record until 1925. On the other hand the Walnut Bacterial Spot appears to have been recently introduced into this country on nursery stocks. Such facts show that a disease may become well established before attention is called to it, and they also point to the necessity for growers to seek advice on any unusual disease which comes their way. A new disease which apparently is of little importance on its first appearance may, under conditions favourable for the parasite, develop into an epidemic resulting in serious loss.

* Kidd, F. and West, C. " Functional Diseases of Apples in Cold Storage." Food Investigation Board, Special Report, 23, 1925.

Of the diseases known or suspected to be caused by parasitic organisms during 1925 the following are perhaps of sufficient interest to warrant brief comments.

Potato Blight (*Phytophthora infestans*).

As noted in the last Report this disease in 1924 appeared on this Station before the end of June. In 1925 it was not noticed here until well into August, a result of the drought period in early summer. The rains of July and August were favourable for the development of the disease and by the end of August it was well on the run. During the first week of September the unsprayed plots on the Station had the parts above ground almost completely destroyed and this condition was general in many potato fields in Kent.

Grey Mould (*Botrytis cinerea*).

During the wetter months of the year rots caused by *Botrytis* were again in evidence. Thus *Botrytis cinerea* was found associated with rots on Hops, Strawberries, Runner Beans, Lettuce, Vegetable Marrows and Roses. The fungus thrives in moist situations and stagnant air; in the cases mentioned, with the exception of hops and roses, the rots arose on those parts of the plants near to, or resting on, the ground and sometimes partially covered with leaves thus retaining moisture. The Grey Mould of hops is described elsewhere in this Report (p. 94). On strawberries the rot was found on two varieties on this Station; only a few fruits were infected but these were completely rotted and covered with the *Botrytis* fructifications. The Grey Mould on runner beans was found on plants on the trial plots on the Station; it was chiefly on plants growing without supports so that pods and leaves were often in contact with the ground and shaded by leaves; both pods and leaves were found rotted and bearing Botrytis fructifications. The rot was later found on beans well above ground level on plants supported on poles. With regard to the rot of roses, the disease was found on bushes growing in a situation shaded by fruit trees. Nearly all the flowers of these particular bushes became infected as they were opening; the partially open buds became discoloured and covered with *Botrytis* fructifications and the rot sometimes extended into the flower-stalk.

Brown Rot Diseases.

Blossom Wilt of Cherries (*Sclerotinia cinerea*) was again prevalent both on the sweet and the acid cherries. On the Morello cherry blossom wilt accompanied by the killing back of twigs was seen in three localities in Kent, and specimens were received from Suffolk.

In the winter (1925-6) Morello shoots (current year's growth) were found, on the Station, killed back and bearing numerous fructifications of the Monilia

stage of *Sclerotinia cinerea*. The symptoms were similar to those of "Wither-tip" in plums and presumably the disease arose in a similar manner, by the infection of the young leaves from which the fungus extends into the axis of the shoots.

A disease of a flowering Japanese cherry, *Prunus serrulata*, characterised by a withering of the tips of the branches is to be attributed to *Sclerotinia cinerea* as this fungus was isolated from the infected bark of diseased twigs; infection probably took place through the flowers, but when the disease came to my notice it was too late to determine how the fungus had entered.

A case of blossom-wilt on an ornamental species of Pyrus, *P. elæagrifolia* was found on a tree growing on the Station; infection had extended into the branch, producing a canker. *S. cinerea* was again isolated from the diseased bark of the branch. The wilt of plum shoots (associated with the presence of *S. cinerea* in the diseased tissues) in the stool rows of the plum stocks on the Station was again noticeable but less serious than in 1924.

A small mummified fruit was found on one of the quince trees on the Station; it bore the conidial fructifications of *S. cinerea*. This fungus is apparently unusual on quinces (I have not seen any reference to its occurrence on this host) although the closely related species, *S. fructigena*, is a common cause of rot on the maturing fruit of the quince. The leaf-blotch of quinces, described on another page, is caused by the fungus *Sclerotinia cydoniæ* which is closely allied to the common brown-rot fungi.

Sclerotinia fructigena, the most common cause of fruit rot in half grown and ripening apple and pears, was very general in the summer and autumn. Most of the rotting fruit dropped and it was no uncommon sight to see the ground under apple trees strewn with fruit almost covered with the yellowish tufts of the *Monilia* stage of this fungus.

An Apple Rot.

In the last Report* reference was made to an apple rot on the stored fruit caused by a species of *Gloeosporium*. A few cases were again found on the Station in 1925. The parasite has been identified as *Gloeosporium album*†, a fungus known on the Continent to cause rotting in apples and pears and recently put on record for this country.‡

Apple Scab (*Venturia inæqualis*).

This disease was responsible for considerable depreciation of the apple crop in 1925. It was by no means uncommon to see apples offered for sale with nearly

* *Loc. cit.*, p. 115.

† I am indebted to Miss E. M. Wakefield, of the Herbarium, Kew Gardens, for examining and identifying the fungus.

‡ Kidd, M. N., and Beaumont, A. Apple Rot Fungi in Storage, Trans. Brit. Mycol. Soc., X., 1924, p. 107.

every fruit spotted. Large quantities of scabbed apples were stored and in some cases this resulted in further loss, for soft rots set in at the scab spots. Specimens of Blenheim Orange sent in for examination at the end of October were found to be rotting and it was seen definitely that the rot had started at the scab infections. *Cephalothecium roseum*, a rot-causing fungus that frequently infects apples through the scab spots, after storing, was present on, and around, the scabs. The grower stated that except for a little scab the apples were sound when put into store.

Many cases were observed where the young shoots of Cox's Orange Pippin were thickly infested with scab infections; on this variety an attempt should be made to cut out such infected wood, as Cox's Orange Pippin is very liable to be injured by sprays if the usual control measures by spraying with Bordeaux Mixture or Lime-Sulphur are attempted.

Towards the end of May two trees of *Pyrus ringo* growing on the Station showed scab infections not only on the leaves but also on the flowers; conidial fructifications were present on pedicels, calyx and even the petals. Another tree, *Pyrus Riversii*, had scab fructifications on pedicels and calyx. These two *Pyrus* species are closely related to the apple and the scab fungus on them is probably *Venturia inœqualis* but whether these species are a source of infection for the apple is not known. If it should prove that the fungus on them is identical with the apple scab fungus it is probable that such highly susceptible species of Pyrus with their heavy infection at flowering time are a dangerous source of infection for the more valuable cultivated varieties if grown in the vicinity.

Cherry Leaf Scorch (*Gnomonia erythrostoma*).

This disease continues to be prevalent and there have been many enquiries as to methods of control. Some years ago Professor Salmon showed* that Bordeaux Mixture, applied just before the trees came into flower and again after the flowers had set, controlled the disease, and where it is impracticable to pick off the dead leaves in winter (the most certain way of dealing with it) Bordeaux Mixture should be tried.

Some growers maintain that this disease causes no appreciable damage to the trees; others declare that it does weaken them. Since the leaves become infected early in the season and are killed prematurely (so that they remain withered on the trees through the winter) it would seem that the disease must reduce the vigour of the trees by the early destruction of the assimilating organs. As accurate information is required on this point the Station would be glad to hear from any grower who has a serious infestation of this disease, preferably on young trees, so that observations could be recorded relative to the damage caused by the disease.

* Jour. S. E. Agric. Coll. No. 15. July, 1906.

Quince Diseases.

Observations have been continued on the incidence of diseases on the quince trees on the Museum plot on the Station and evidence is accumulating that some varieties are far more susceptible to certain diseases (e.g. fruit and leaf spot (*Fabræa maculata*) and mildew (*Podosphæra leucotricha*) than others. The fruit of quince trees is not perhaps in itself a very valuable crop, though quince orchards are occasionally met with. As stocks for pear trees however the quince is of considerable value and from the nurseryman's point of view the diseases of quinces are worthy of notice. One nurseryman writing of a disease in his quince stool beds, a disease which on examination proved to be the leaf spot mentioned below, said, " One result of the disease is that the leaves drop very early and our cutting beds had lost most of their foliage by the end of August. The disease first appears in the shape of spots then the foliage turns yellow and commences to drop in July. Many of our cuttings which have made three to four inches growth (top) and corresponding roots have died out entirely."

The problem as to the best means of raising disease-free quince stools, for the supply of stocks for pears, can only be solved by a close study of quince diseases with this object in view.

Quince leaf spot was again causing considerable damage to the foliage of some of the trees in the variety rows ; on the most seriously infected trees there was early defoliation, but, as there was very little fruit during the past season on any of the trees, observations on the effect of the disease on the crop were not available. It was noticed that the young leaves became infected early in the season. It was then observed that infection was worst on those trees which had dead shoots bearing fructifications of the fungus and it appeared highly probable that the leaves were infected from the fungal fructifications on the dead twigs. A little later it was found that the young current year's shoots also bore lesions caused by the fungus. A feature, which may have an interesting bearing on the early infection of the leaves and shoots, was that towards the end of June, when the leaves were showing young infection spots, small yellowish " spring-tails " were seen running and leaping on the dead twigs and over the leaves. Whether these creatures serve as a means of disseminating the spores of the fungus has not yet been ascertained but the fact that they were very agile and were found not only on the young green leaves but also on the old dead twigs suggests that they may carry the spores from these shoots (on which the fungus exists through the winter) to the leaves.

Bitter Rot caused by *Gloeosporium fructigenum* was found on the fruit of a quince tree in a garden at Maidstone. It was very late in the season when my attention was drawn to this disease and as only very few of the fruits were left it was impossible to estimate the amount of damage done.

The leaf-blotch of quince trees on this Station is described on another page.*

Root Rot of Fruit Trees (*Roesleria hypogæa*).

Young plum trees, one year and two years old, of various varieties (Victoria, Czar, Monarch, Purple Egg and Pond's Seedling) grafted on a number of stocks (the stocks including those most generally used, viz., Brompton, Pershore, Brussels, Common Mussel, Common Plum, and St. Julien de Toulouse), on being removed from the nursery beds for transplanting to permanent quarters were found to have in very many instances the fungus *Roesleria hypogæa* on the lower end of the stock and on some of the roots. The trees otherwise seemed quite normal and healthy, and the fungus had evidently caused little or no damage. Young peach trees (variety Hales' Early) on various plum stocks were also found with this fungus on the stocks. The removal of stocks from the stools results in a certain amount of injury and the tissues killed in the operation apparently serve as a starting place for the fungus.

Young fruit trees which die soon after they are planted out are frequently found, when taken up, to have this fungus on their roots (instances were given in last year's Report). *Roesleria hypogæa* is usually supposed to be parasitic but there appears to be no exact information as to the direct damage actually caused by the fungus in this country.

Raspberry Diseases.

The investigation of these diseases at this Station has resulted in specimens being sent in from various localities and there is increasing evidence that raspberry diseases are generally distributed throughout the country, in many cases causing considerable loss. Canes showing the Blue Stripe Wilt (*Verticillium sp.*). have been received from such widely separated counties as Yorkshire, Glamorganshire, Worcestershire, Cambridgeshire and Kent.

Specimens showing Cane Spot (*Plectodiscella veneta*) were also sent in from several counties. The suspected relation of this disease with that known in America as " Anthracnose " of raspberries has received confirmation during the year by the discovery on the spots of the two stages of the fungus, the perfect (*Plectodiscella*) stage and the conidial stage, formerly known as *Gloeosporium venetum*.

The Mosaic disease of raspberries appears to have been more virulent in 1925 than in previous years. Stools showing an extreme form of the disease, as seen by very dwarfed canes and distorted foliage were found on the Station and a similar case was brought to our notice by a grower at Ilford.

Besides the diseases mentioned above, canes on the Station and others sent in from various localities, showed diseased areas, chiefly round the buds, greyish

* See page 87.

in colour and dotted with fructifications of several fungi. To what extent these fungi are responsible for damage to the canes in this country has not been ascertained, though one of these, *Didymella applanata*, has been found in circumstances suggesting that it is responsible for a certain amount of damage.

In September, Raspberry Rust (*Phragmidium rubi-idæi*) was found on the variety Baumforth B on the Station; other varieties around were apparently free from this disease.

Currant Leaf Spot (*Pseudopeziza ribis*).

This disease, though generally ignored, is capable of causing considerable damage to the foliage of certain varieties of black currant. The Baldwin variety appears to be particularly susceptible. Specimens were received early in July showing many leaves badly spotted and some completely withered. The grower wrote to say that "in every case (on those particular bushes) the fruit is withering and the foliage assuming a rusty tint and falling while the wood has made no growth at all."

The bushes were described as "rogues mixed up in a plantation of Boskoops." From the specimens the diseased bushes were identified as Baldwins and the difference between these and the Boskoops (with regard to the intensity of the disease) must have been striking for the grower goes on to say, "These bushes have had the same treatment as the Boskoops which appear to be quite healthy."

About the middle of July a visit was paid to a grower at Cranbrook who had a plantation of three varieties, viz., Baldwin, Boskoop Giant and Carter's Champion. All three were infected with the *Gloeosporium* stage of the fungus. The infection was worst on the Baldwins and in this variety there was a serious leaf-fall of the lower infected leaves. On the two other varieties there was at the time no evident leaf-fall but much of the foliage was badly spotted.

Seedling black currants are often very subject to infection. In cases on the Station, seedlings a few inches high have had all their leaves spotted.

American Gooseberry Mildew on Black Currants.

American Gooseberry Mildew (*Sphaerotheca mors-uvæ*) sometimes attacks the black currant. One instance came to my notice in August. The fungus was present on the leaves only and not on the shoots themselves as in the gooseberry. The white Oidium stage was mostly on the lower surface of the leaves but a few spots were observed on the upper surface. On some leaves the dark-brown mycelium (of the so-called winter stage) with the perithecial fructifications had developed. The thickly infected leaves towards the tips of the shoots were distorted.

FIG. 1. A hop runner with two young bines, one normal, the other a " Spike."

FIG. 2. A hop bine of the "Spike" form infected with Downy Mildew.

European Gooseberry Mildew (*Microsphæra grossulariæ*).

In August the European Gooseberry Mildew was found on gooseberry leaves received from Goudhurst and from Bearsted; in the latter case the bushes were shaded by apple trees and this was undoubtedly one factor concerned in the intensity of the attack. Although this disease (unlike American Gooseberry Mildew) does not infect the fruit the leaves may become very badly mildewed. It is often confused with the more serious American Gooseberry Mildew.

Hop Diseases.

The Downy Mildew* of the hop (*Pseudoperonospora humuli*) appeared early in May in the "spike" form; this is characterised by the shortened internodes and diseased bines are therefore readily detected by their dwarfness and their crowded leaves. Such leaves are usually paler on the upper surface than those of normal bines, and their lower surface bears the dark grey downy fructifications of the fungus. Similar spikes were also found about the same time on wild hops on the railway bank at East Malling. As this disease is unfamiliar to many hop-growers the appearance of a "spike" as contrasted with a normal bine is here illustrated (see figures 1 and 2). Mr. W. F. Cheal about the middle of May informed me that in a hop-garden of five acres in the Canterbury district he found 233 hills with one or more of these infected spikes. Towards the end of May the leaf-spot phase of the disease (dark angular spots about 1 mm. in diameter), the spots being very numerous on some leaves, was observed in a hop-garden at Wateringbury where there were also numerous spikes. Hop cones infected with the Downy Mildew were found on the Station about the middle of August, and later in the month infected hop cones were also found near Paddock Wood.

One grower brought specimens showing a disease of hop cones characterised by a brown discolouration of the tips of the bracts, so that the cones bore some resemblance to those attacked by the Downy Mildew. The cause of this particular form of disease was not ascertained; a species of *Cladosporium* was found on a number of the dead tips of the bracts but it is doubtful whether the fungus was really parasitic.

The wilt disease of hops, probably caused by a species of *Verticillium* which is constantly found in diseased bines, appeared again in the same hop garden in which it was observed in 1924. This particular form of hop wilt has not been found with certainty in any other hop garden up to the time of writing. A

* This disease is under investigation by Prof. E. S. Salmon and Mr. W. M. Ware, at the South-Eastern Agricultural College, Wye; a description of the disease and the fungus causing it will be found in the *Journal of Agriculture*, Vol. XXXI., No. 12, March, 1924, and a more detailed account in Ann. Appl. Biol., XII., No. 2, May, 1925.

more detailed account of the symptoms of this disease appears on another page (see page 92).

In August, Mr. Cheal called my attention to the fact that a species of *Gibberella*, which we had previously seen on dead hop "straps" lying about in hop gardens after cutting operations, was present on the lower end of hop bines just wilting. It was also found on the cut surfaces of hills, i.e., the surfaces left during the ordinary cutting in winter. It is suspected that this fungus is concerned with Hop Canker but inoculation experiments have so far given inconclusive results.

Grey Mould of hops is described on p. 94.

CELERY LEAF BLIGHT (*Septoria apii*).

This disease appears to have caused considerable damage during the past year, a number of cases being brought to our notice. From the enquiries received it would seem that it is not generally known that Celery Leaf Blight can be successfully controlled by spraying with either Bordeaux Mixture or Burgundy Mixture. In February, a sample of "seed" (variety Standard Bearer) was submitted for examination and the fructifications of the fungus were found on some of the "seeds."

OTHER FUNGOUS DISEASES.

Other diseases which may be mentioned as noticed during 1925 are as follows:

A Leaf Disease of Elæagnus. Leaves of *Elæagnus pungens* var. *variegata* showing diseased areas were received from Hayling Island, Hampshire. The spots were white, or almost so, bordered by a distinct dark line, and they were dotted with the fructifications of a fungus, *Phyllosticta argyrea* of which no previous record can be found for this country. An interesting feature of this disease is that on the leaves examined (about twenty in all) the diseased areas were confined to the pale marginal zones of the variegated leaves, the green portions of the leaves being invariably free from the disease.

A Leaf Spot of Snapdragons, caused by *Cercosporella antirrhini* was found on the plants planted out in the beds on the Station. The plants were not seriously affected but the same disease was observed in a garden at Bearsted and in this case the appearance of the plants was spoiled by the numerous spots on the leaves, the diseased parts sometimes falling out with a "shot-hole" effect.

Pod Spot of Peas caused by *Ascochyta pisi* was seen on early peas in a garden at East Malling; in this case no great harm was caused although this disease may be troublesome at times.

Crown-gall of Lucerne caused by the fungus *Urophlyctis alfalfæ* was found in a field of lucerne on the Station.

Diseases associated with Bacteria.

Bacterial diseases of plants have, until recent years, been studied only in a few isolated instances in Britain. It is now known that such diseases, which are prevalent in America where they have received considerable attention, are by no means negligible in this country. During the past year several diseases, associated with the presence of bacteria in the lesions under conditions which lead one to suspect they are the cause of the trouble, have come under observation. In addition to bacterial diseases mentioned in last year's Report the following have shown bacteria present in the diseased parts; some of these are known to be of bacterial origin, but in other cases proof is at present lacking that the bacteria in the lesions are the actual cause of the injury.

A Bark Canker of Pears. Some 300 Catillac pear trees in a plantation, near Paddock Wood showed cracked cankered bark towards the base of the stem; about twenty of the trees succumbed. In the specimens examined the bark only was affected and the grower said that the damage in the first place was confined to the bark. Fungal hyphæ were to be found in the dead bark but in the case of young cankers bacteria were swarming where the diseased tissues bordered on the healthy. A bacterium has been isolated from diseased bark but its parasitism has not yet been tested.

A Bacterial Leaf Spot of Fertility Pears. A number of young Fertility pear trees on the Station showed a spotting of the leaves; the spots were small but often very numerous on the more severely infected leaves. The diseased spots were found to be crowded with bacteria. An organism was isolated and preliminary inoculation experiments have shown that blackened lesions could be caused by inserting the organism into punctures in leaves, while control punctures did not show the blackening. The organism has not yet been identified.

A Bacterial Spot of Walnut Leaves. A young walnut tree (one of a number planted up in the winter of 1924-25 for trials on the Station), was found to have its leaves badly spotted. The spots were full of bacteria. Plates prepared from one of the spots showed two types of bacteria to be present, a white organism and a yellow one. A bacterial leaf spot of walnuts is known in America; this has been found to be caused by a yellow organism *Pseudomonas juglandis*. Whether the disease found on this Station is the same as the American has not yet been determined.* One point of interest is that the young trees were obtained from a French nursery and it is suspected that the disease

* While this article was in the press, inoculation experiments have shown that the yellow organism isolated is pathogenic, and in preliminary cultural tests has behaved as *P. juglandis*.

was introduced on the tree itself. It should be noted that if this leaf-spot should prove to be caused by *Pseudomonas juglandis*, it is a disease that must receive careful consideration in view of the fact that attempts are being made to rouse interest in the cultivation of walnuts in this country. This organism has been shown to be a most serious menace to walnuts in America, particularly in California, where it damages not only the leaves but also the young shoots and the fruit.

A Leaf Spot of French Beans. Leaves of French beans growing on the Station were marked by blotches; the younger spots had a water-soaked appearance but the tissues of the older spots were dry and withered. Bacteria were present in the lesions and the symptoms generally were similar to those described for a bacterial disease of beans in America caused by *Bacterium phaseoli*.

Black Rot of Cruciferous Plants. A disease of broccoli and savoys on the Station was seen in a yellowing of marginal portions of the leaves. The veins of these portions were blackened and bacteria were present in the vessels. The symptoms correspond to those of the Black Rot of cruciferous plants a disease which does considerable damage in America and is caused by *Pseudomonas campestris* (*Bacterium campestre*). An organism giving reactions in culture similar to those of *Pseudomonas campestris* has been isolated from the lesions.

A Parasitic Flowering Plant.

A Broom Rape parasitic on Pelargonium. Parasitic flowering plants are rarely met with in horticultural practice so that the occurrence of a case on this Station may be of some interest. Geraniums (*Pelargonium zonale* var. *Paul Crampel*) were being raised for experimental work in the propagating house and in one pot the flowering spike of a Broom Rape (*Orobanche minor*) appeared in spring. Later it was found that the basal end of the spike was attached to a root of the host plant. It may be supposed that the soil in which the geranium was growing contained one or more seeds of the parasite; a seedling attached itself to a root of the geranium and thrived at the expense of the latter which however seemed little the worse for this drain on its resources. Although this may have little economic significance it is conceivable that if such combinations of parasite and host plant (in pots) could be raised at will they would serve as convenient examples (for educational purposes) of this type of parasitism.

Broom Rape (*Orobanche minor*) growing parasitically on a Geranium (*Pelargonium zonale* var. *Paul Crampel*).

FIG 1. Blotch on Quince Leaf caused by *Sclerotinia Cydoniæ*.

FIG. 2. Infected Quince Shoot with wilting leaves. The conidial fructifications are seen as a whitish layer along the mid-rib and main veins.

A LEAF BLOTCH OF QUINCE TREES.*

By H. WORMALD.

Early in May, 1925, the quince trees in the "Museum" plot on this Station were examined for the incidence of the common leaf-spot disease caused by *Fabræa maculata*. On some leaves however there was an unusual form of disease. Instead of the numerous, small, somewhat angular spots characteristic of the lesions caused by the leaf-spot fungus, these particular leaves had each a dark blotch occupying a considerable portion of the leaf surface and in some cases the whole of the leaf was so discoloured. In a few instances the young shoots themselves became infected and wilted. When the disease was first observed there was no obvious indication as to the cause of the trouble but the general resemblance of the symptoms to those of a leaf disease of the medlar suggested a close relationship of the two. The medlar leaf blotch caused by the fungus *Sclerotinia mespili* was recorded for this country in 1920, in which year it was found in four localities in Kent and one in Somersetshire. This medlar disease has been known on the Continent for many years and a similar quince disease caused by *S. cydoniæ* has also been found in several European countries. It was suspected therefore that the leaf disease found on the quinces at East Malling was the one known to occur on that host on the Continent.

Some of the infected leaves were collected and placed on moist filter paper in a covered glass dish. Within a few days a pale greyish mould appeared along the veins of the leaves and on examining diseased leaves on the trees about the same time it was found that some of them too were giving rise to a similar mould-like growth. Microscopic examination showed the mould to consist of chains of spores which from their size and shape were similar to those described for *Sclerotinia cydoniæ*. The chains of spores are rather like those of the Monilia fructifications of the common Brown Rot fungi *Sclerotinia fructigena* and *S. cinerea*. In the quince leaf-blotch fungus however the spores are connected in the chains by means of small spindle-shaped bodies known as "disjunctors" and these are present also in the medlar leaf-blotch fungus.

On removing the lid of the dish in which the infected leaves had been kept it was noticed that the leaves emitted a sweetish aromatic odour; this again is a character common to both the quince and the medlar leaf-blotch diseases. It is supposed that the odour of the infected leaves serves to attract insects which carry away some of the spores, and should these insects next visit the

* A more detailed account of the fungus causing this disease has been submitted for publication in the Transactions of the British Mycological Society, Vol. X., p. 303, February, 1926, and the plates are reproduced by permission of the Editor and Publishers of that Journal.

quince flowers spores are deposited on the flowers, which in turn become infected. The infected flowers fail to develop further; they become permeated with the fungal threads (hyphæ) and persist as "mummies." Later these "mummified" undeveloped fruitlets fall to the ground and give rise to a second form of fructification resembling a stalked cup; this stage in the life history of the fungus has not yet been found in this country.

How the disease arose on the Station is not known. When the medlar leaf-blotch was found in this country it was suspected that the related quince fungus might also be present in Britain and the particular trees on which the disease was found in 1925 had been carefully examined the previous year but no trace of the disease could then be found. About the same time that the disease was seen at East Malling it was also observed at the Royal Horticultural Society's Gardens at Wisley, and Mr. W. J. Dowson, the Mycologist there, kindly sent specimens for comparison. The disease symptoms and the fungus present were found to be similar to those of the East Malling specimens. It would seem then that the weather conditions in 1925 were in some way particularly favourable for an outbreak of this disease which had probably been present previously in traces and had not been noticed.

From the economic standpoint, apart from the actual damage caused on the quince and medlar trees themselves by these diseases, the question arises:— Are the Sclerotinias of these two hosts able to attack other fruit trees? In a case which came to my notice in 1920, when making observations on the medlar leaf-blotch, four large Medlar trees with many infected leaves were situated in a cherry orchard and the grower was anxious to know whether the medlars were in any way responsible for an outbreak of Brown Rot in the cherries. In another instance two infected medlar trees were in a mixed orchard of plums and cherries, and again the grower enquired whether the quinces were a source of danger to the fruit trees. On this Station the infected quince trees too are in the vicinity of various kinds of fruit trees. As already mentioned *Sclerotinia mespili* and *S. cydoniæ* are quite distinct from the common Brown Rot fungi of other fruit trees and the latter are not known to be attacked by them. There is no reason to suspect therefore that the two fungi responsible for Leaf Blotch in quinces and medlars respectively are able to cause infection of either plums or cherries.

BACTERIAL ROT OF TURNIPS.*

By H. WORMALD and R. V. HARRIS.

Turnips in the field and garden often go completely rotten and are reduced to a soft pulp. If a particle of such a root is examined under the microscope it will be seen that the tissues are disintegrated by the cells becoming separated from one another, and swarms of actively motile rod-shaped bacteria will also be observed in the pulpy mass. That bacteria are able to produce such a rot in various vegetables has been clearly shown by a number of investigators in this country and abroad. In 1900, L. R. Jones, an American plant pathologist, proved that a bacterium which he isolated from rotting carrots readily reproduced the rot not only on carrots but on various other vegetables, including turnips. This organism he named *Bacillus carotovorus* and it has since been found that bacteria, answering to Jones's description of the carrot organism, are responsible for rots in many plants. In this country *B. carotovorus* has been found causing a rot of turnips, celery, potatoes, violets, arum lilies, cucumber, melon, roots of runner beans, and tomato stems and fruit.

With regard to the rot in turnips there have been diverse opinions as to the identity of the organism or organisms causing bacterial rot of this crop in the British Isles. A bacterial soft rot of turnips was recorded for this country by Professor M. C. Potter in 1899. The organism he isolated and worked with was a rod-shaped bacterium which was motile by means of a single long flagellum at one end of the rod. He named the organism *Pseudomonas destructans*, the genus *Pseudomonas* being characterised by the organs of motility, the flagella, being at the end (or " pole,") of the rod. Some years later two American workers, Harding and Morse, when collecting material for a comparative study of the soft rot bacteria received from Professor Potter, not his original organism, which he no longer had, but another bacterium which had been freshly isolated. The latter was found to show no essential difference from Jones's type strain of *Bacillus carotovorus* ; instead of a single polar flagellum it had a number of flagella distributed over the surface of the rod, a character of the genus *Bacillus*. The American workers were sceptical as to the nature of Potter's original organism for they wrote " The failure of Professor Potter to re-isolate a Pseudomonas from decaying vegetables is not surprising in view of the fact that during the years in which we have been frequently making such isolation we have never isolated a white liquefying Pseudomonas producing this decay."

Since that time, however, other workers have found an organism corresponding to Potter's *Pseudomonas* associated with rot in turnips while others

* This article is adapted from a paper entitled " Note on the Bacterial Soft Rot of Turnips," which appeared in " The Annals of Applied Biology," XII., No. 3, July, 1925.

have found a *Bacillus*. Whether the organism causing bacterial soft rot of turnips in the British Isles is in the majority of cases to be attributed to *Bacillus carotovorus* or to a species of *Pseudomonas*, or whether, as some investigators suggest, the two types of flagella distribution may be shown by one and the same species, is outside the scope of this article and can only be determined by a more intensive comparative study of turnip-rot material from various parts of the country. We have recently however had an opportunity of making a few observations on the disease when we found almost the whole crop of turnips destroyed in a small plot in a garden at East Malling. In every specimen examined it was seen that the rot started in the neighbourhood of the crown and extended downwards until the fleshy parts of the roots were reduced to a pulp and washed out by rain into the soil leaving only, in some cases, just the fibrous network. Such a skeletonised turnip is shown in Fig. 1.

The rot-producing organism was isolated from a partially rotted turnip; when stained it was seen to have a number of flagella as in the genus *Bacillus* and from the various cultural tests applied it proved to correspond to Jones's *Bacillus carotovorus*. It was found possible to induce the rot in young turnip plants by placing the bacterial slime, taken from a pure culture, in punctures on the leaves. Such a plant is seen in Fig. 2, the photograph being taken five days after the plant on the left had been inoculated in this way on the leaf-stalks; the plant on the right was similarly punctured but no bacteria were placed in the punctures.

Inoculations with the turnip organism were also made on a number of other vegetables and rot was produced on the leaf-stalks of cauliflower, swede, carrot and celery. The result on celery leaf stalks is shown in Fig. 3.

Various workers in this country and abroad have shown that *Bacillus carotovorus* isolated from one host can infect a number of others. Thus one of us* found that a strain from celery caused rot when inoculated into young leaf-stalks of turnip, radish, parsley, carrot, broccoli, cauliflower, cabbage and parsnip, and into young potato shoots. Miss Lacey† with *B. carotovorus* isolated from violets, was able to infect carrot, turnip, potato and onion, while Butcher‡ showed that a strain from tomato stem was able to infect not only tomato stems but also cucumber (fruit), capsicum, radish (root), turnip (root), mangold, potato, carrot, lettuce, cabbage, celery, and cyclamen corm.

Dr. Erwin F. Smith§, an American authority on plant bacteriology writes of the rot caused by this organism, " The disease has been seen in the United States occurring naturally or has been obtained artificially by pure-culture

* Jour. Agric. Sci., VIII., Part 2, March, 1917.

† Annals Appl. Biol., IX., No. 2, June, 1922.

‡ Tenth Annual Report, 1924, Cheshunt Experimental and Research Stn.

§ An Introduction to Bacterial Diseases of Plants, 1920, p. 225.

FIG. 1. A Turnip with all the softer parts rotted away by *Bacillus carotovorus*.

FIG. 2. Two young Turnip plants, five days after the leaves of the plant on the right hand had been inoculated from a pure culture of *Bacillus carotovorus*.

FIG. 3. Inner leaves of a celery plant three days after inoculation with *Bacillus carotovorus* isolated from Turnip.

inoculations on the following plants: carrot, parsnip, celery, lettuce, cabbage, cauliflower, turnips, radish, cucumber, musk-melon, potato, tomato and pepper (ripe and green fruits—faster on the latter), egg plant (ripe fruits), hyacinth (leaf and scape), and onion (bulb and leaf)."

There is a mass of evidence therefore proving that *Bacillus carotovorus* is able to attack not only the turnip, but also a very large number of other plants with fleshy organs. Experiments have shown that the very sappy rapidly growing parts are far more easily infected than the older, more fibrous tissues; thus in our experiments on turnips the very young leaves of the crown were readily rotted by the organism and this corresponds to our observations in the open where it was seen that in the naturally infected turnips the rot often starts near the centre of the crown. Again in celery the younger inner leaf-stalks are more easily infected than the older ones and in this crop bacterial infection in the field or garden usually takes the form of a "heart-rot." The organism requires a moist substratum not only for growth but in order to exist at all, for it is found to be very easily killed by dry air; when left exposed in air it succumbs almost immediately on the disappearance of visible moisture.

The control of this disease in the field is, from the nature of the case almost impracticable. In the garden it is possible, by removing infected plants as soon as the disease appears to prevent infection extending from these to other plants in the vicinity. Slugs are probably agents in the dissemination of the disease by crawling from diseased plants to healthy ones and not only carrying the organism with them but eating into the fleshy parts and so making wounds for the bacteria to get in. To reduce the number of slugs in a garden may be possible but it is not a practical proposition in the field.

When the crop is taken up from either field or garden care should be taken not to store rotting roots with the healthy ones and the latter should be stored in a cool dry place.

A WILT DISEASE OF HOPS.

By R. V. HARRIS.

1. Introduction.

In September, 1924, the writer was asked to investigate a suspected outbreak of canker in a Hop Garden at Penshurst (Kent) where a large proportion of hills of the variety "*Fuggles*" showed wilting bines. On examining the diseased hills however the symptoms were found to differ considerably from those of *Hop Canker* or "Growing Off" as described by Salmon and Wormald.* One of the chief points of difference was the absence of pustules of the canker fungus (*Fusarium* sp.) on the outside of diseased bines, the bark being quite normal in appearance. On cutting the bines near the base however, the wood was found to be uniformly discoloured, the discolouration often extending up the bine for a considerable distance from the crown. On examining the sections of the discoloured wood under the microscope the vessels were found to be infested with delicate fungal hyphæ. Small portions of the diseased wood of numerous affected bines were transferred to dishes of nutrient medium and in every case a fungus, which was identified as a species of *Verticillium*, grew out in a pure condition. The following season an outbreak of the disease again occurred and the symptoms were found to be the same as in the previous season the diseased bines again yielding in every case the same fungus. The constant association of this particular fungus with the disease and the fact that the symptoms are very similar to those of diseases in other crops caused by species of *Verticillium* strongly suggest that this fungus is the cause of the wilt. Inoculation experiments have, however, up to the present yielded negative results. Meanwhile it has been thought advisable to place a summary of the symptoms of the disease on record so that it may be identified by growers.

2. Symptoms of the Disease.

The first symptom noticed was a wilting, yellowing and withering of the leaves of one or more bines of the affected hill. In some cases this happened when the cones were about half-grown, but more commonly the symptoms did not appear before the hops were ripening. The lower leaves were the first to wilt followed by the other leaves in succession and finally the cones changed colour and withered. When diseased bines were tugged they came away very easily, invariably bringing a piece of the crown of the hill with them and not "growing off" above the crown as in the case of "Canker." The disease could be detected in bines before the leaves wilted by this easy detachment from the crown. The extent to which a hill was affected varied greatly.

* Journ. Min. Agric., XXIX., July, 1922, p. 354.

In some hills only one of the bines was affected. In others several or even all of the bines were dead or in process of wilting and many hills were completely killed by the disease.

On digging up severely affected hills large portions of the tissues of the crowns were found to be discoloured and in a rotting condition. In the season of 1924 it was calculated that about 40 per cent. of the bines in the affected gardens at Penshurst showed symptoms of the wilt.

3. Control.

The study of the disease up to the present date, as outlined above, suggests certain precautionary measures against the spread of the disease.

As the main seat of the fungus suspected of causing the disease is in the crown of the hill all badly affected hills should be grubbed and burnt. As the fungus is also present in the wilting bines, the practice of using the old bines as green manure for the garden should be avoided and all bines cut as soon after picking as possible and burnt.

The only variety found to be affected up to the present is "Fuggles." The "Tutsham" variety grown in the same garden at Penshurst has shown no trace of the disease.

No evidence of infection in gardens of other localities has yet been found. If any growers therefore observe any of the symptoms detailed above in their gardens, they are requested to communicate with the East Malling Research Station.

THE GREY MOULD OF HOPS.*

By H. WORMALD and W. F. CHEAL.

In September, 1924, a bed of young hop plants growing in a field on a neighbouring farm, was examined for the incidence of Downy Mildew (*Pseudoperonospora humuli*). This particular fungus was not found on them, though many leaves were seen to have discoloured blotches, greyish in the centre but bordered by a dark purplish brown line and then a yellowish zone gradually merging into the general green of the normal leaf surface. These discoloured spots were mostly $\frac{1}{5}$ to $\frac{1}{2}$ in. in diameter but, in some cases, irregularly-shaped areas, nearly 1 in. in length, were found; these were probably the result of several spots coalescing. The smaller isolated spots were almost circular. In most cases only one spot was present on a leaf, but sometimes three or four were on the same leaf.

On examining the underside of infected leaves it was found that in every case a fungus was growing out from the diseased spot. A microscopic examination showed the fungus to be *Botrytis cinerea*, a common cause of rot in a number of plants.

The plants showing the disease had been raised from sets which had been planted the previous year; they had not yet been transferred to their permanent quarters and were not "trained." The ground was overrun by weeds, and this, together with the persistent wet weather experienced at the time, was probably responsible for conditions that favoured infection by the fungus.

The disease in this particular case was not causing any appreciable damage to the plants apart from the death of the leaf-tissue on the spots, and the degree of infection was obviously due to the unsuitable conditions under which the plants were growing.

Characteristics of Grey Mould Disease.

The same fungus, however, may also occur on the hop cones when the damage caused is a more serious matter. In September, 1925, several cases came to our notice where hops were turning prematurely brown at the tip. In some instances the Botrytis fructifications were already present and, in every case where a hop showed the characteristic browning, Botrytis fructifications appeared on the brown parts within from one to two days of keeping such hops in moist air. In all the specimens examined it was seen that the disease started at the tip of the cone and was extending backwards towards the stalk end. This

* This article is reprinted from the Journal of Ministry of Agriculture (Vol. XXXIII., No. 5, August, 1926, pp. 456-8) by permission of the Editor and of the Controller of H.M. Stationery Office.

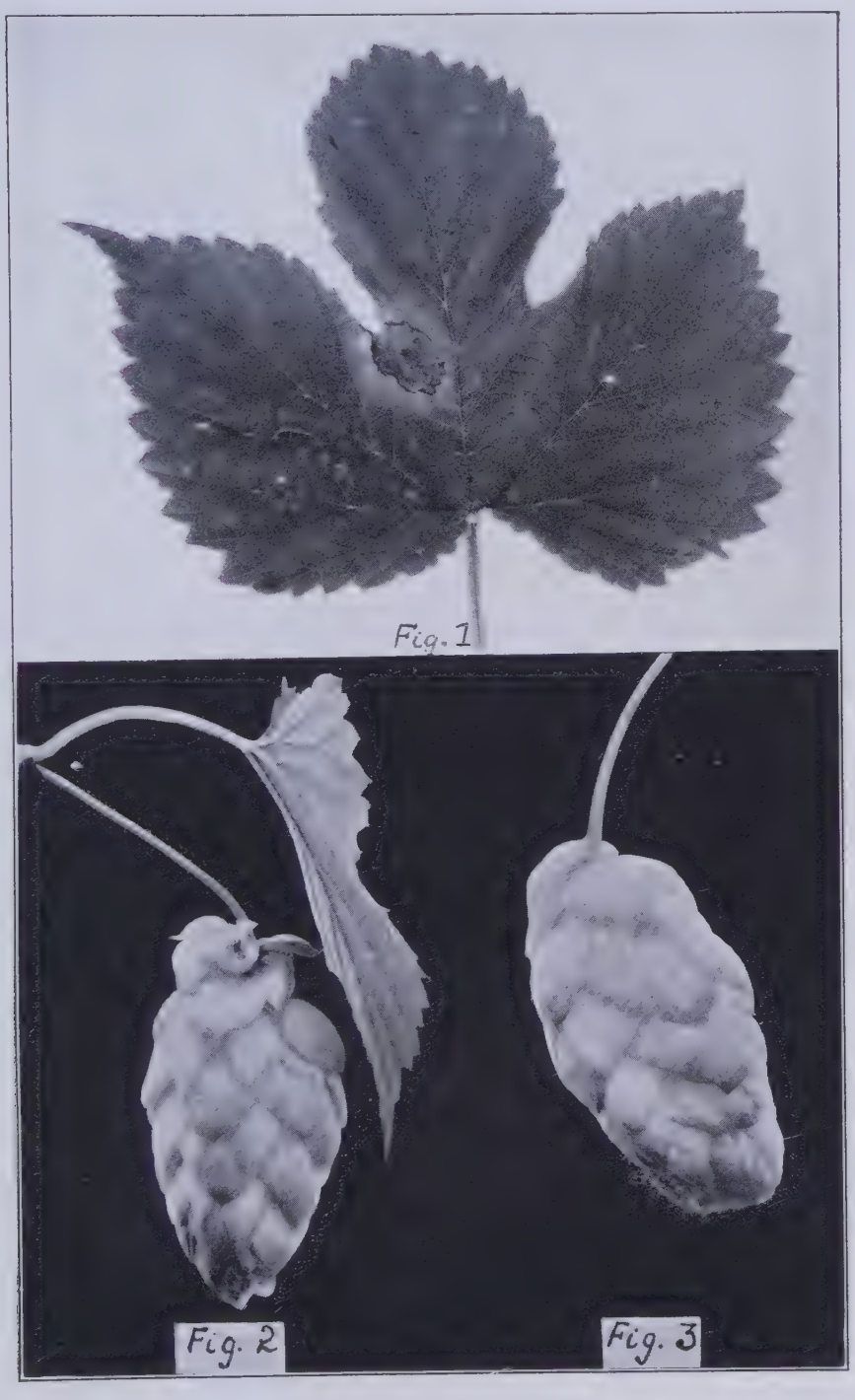


FIG. 1. Hop Leaf, showing a *Botrytis* Spot.

FIG. 2. Hop Cone with brown tip; the *Botrytis* fructifications have not yet appeared.

FIG. 3. Hop Cone with brown tip bearing *Botrytis* fructifications.

suggests that drops of rain water or dew accumulate at the tip of the cone and act as "infection drops," in which the fungal spores are able to germinate and infect the bracts and bracteoles. In this case the bracts and bracteoles are attacked equally, producing a very distinct brown tip to the cone, and by this effect hops infected with Grey Mould can be distinguished from those attacked by Downy Mildew. In the latter case the disease usually appears (on the cones) on the bracts first, causing the hops to have a striped appearance, and is not confined to the tip.

Up to the present the Grey Mould disease has been seen by us on three varieties, viz.: Tutsham, Cobbs and Tolhurst. On the Tutsham variety it was found in four localities—East Malling, Wateringbury, Seal and Chilham. It was plentiful on this variety in three fields at Wateringbury. The worst case of all was on Tutshams trained on pole work.

On a diseased hop which had been kept in a moist atmosphere for about a fortnight the fungus produced a number of sclerotia; these are dense masses of fungal threads, whitish at first, but later black at the surface. Those found on the hop mentioned were about one-eighth of an inch in length. These sclerotia enable the fungus to survive during unfavourable periods, but, when conditions are again suitable, they give rise to Botrytis fructifications and so serve to disseminate the fungus.

Precautions against Infection.

These sclerotia have not yet been observed by us on hops in the open, but it is highly probable that they develop on infected hops which are left hanging, for *Botrytis cinerea* readily produces such sclerotia in the tissues of any host which it attacks. Brown discoloured hops are often left hanging when the rest are picked. If the browning is caused by a parasitic fungus, as in the present case, it is a bad practice to leave such hops to become overripe and shattered, as the shattered hops carry the fungus to the ground, where it either continues to develop or remains in a resting stage (in this case in the form of sclerotia) through the winter and may then cause further infection in the following season.

Botrytis cinerea and related species usually require very moist conditions or a moist substratum (such as soft and sappy vegetable tissues) on which to thrive and cause rotting. The disease mentioned here is not likely to be troublesome except in over-crowded hop-gardens, and in a wet season; but hop growers are advised to take the precaution of preventing the infected hops from shattering, and of having them collected and burnt.

A DISEASE OF THE SHASTA DAISY.

By H. WORMALD.

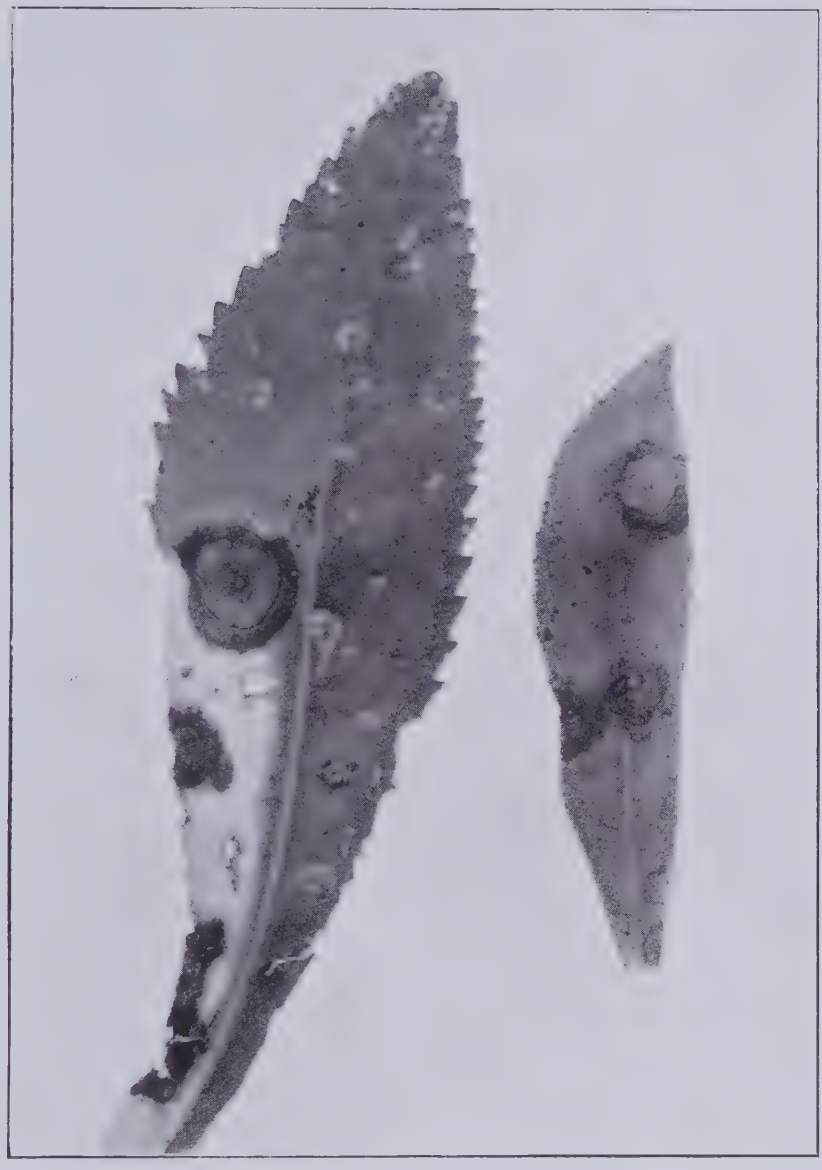
In August, 1925, my attention was drawn to the unhealthy appearance of certain plants of the Shasta Daisy (*Chrysanthemum maximum*) growing in a garden at Bearsted. Some of the leaves were withered and others showed large brown spots or blotches usually almost circular and the largest nearly an inch in diameter. A characteristic feature of the larger blotches was that they were marked by concentric circles slightly raised giving them a zoned appearance. On examining the blotches with a lens numerous small black dots were visible. These dots proved to be the fructifications of a fungus and on teasing one of them out in a drop of water on a slide and examining under a microscope it was found to contain numerous thread-like spores. Later, on keeping the leaves in a moist atmosphere for a few days each fructification exuded its spores through a pore, opening on to the surface of the leaf. The spores emerged as a viscid mass in the form of a droplet, or in some cases, as a curled hair or "tendril." In water the spore mass breaks up into its component spores which are probably dispersed by rain.

The form of the fructification and the shape of the spores indicate that the fungus is a species of *Septoria*. A fungus *Septoria chrysanthemella* is known to occur on varieties of *Chrysanthemum indicum* in this country, being first recorded for Britain by Professor Salmon* in 1908, and at first it was thought that the one found on the Shasta Daisy might be that fungus, but measurements showed that the spores of the Shasta Daisy fungus were much larger than those of *S. chrysanthemella;* they were frequently found to be 100 μ or more in length while the maximum for *S. Chrysanthemella* is 70 μ.

As the disease appeared to be something new to this country specimens were sent to Kew, where Miss E. M. Wakefield identified the fungus as *Septoria lencanthemi* and stated that no previous record of its occurrence in Britain could be found although it is known on the Continent. A brief description was therefore written up and sent to "The Gardeners' Chronicle" for publication. In that article I wrote† "Although it appears that this disease has not previously been reported for this country it is probable that it occurs in localities other than the one here mentioned, and when the Shasta Daisy is showing disfigured leaves it should be examined for the symptoms here described." Within two or three days of the publication of that article I received a letter from Mr. J. Staley, of Hayling Island, Hampshire, who wrote, "It may interest you to

* Report on Economic Mycology, S.E. Agric. Coll., Wye, 1908, pp. 79-82.

† *The Gardeners' Chronicle*, Vol. LXXVIII., No. 2,027, October 31st, 1925, p. 353.



Leaf Blotch of the Shasta Daisy.

know that I found a Septoria disease on one of the *Chrysanthemum maximum* varieties in September, 1915." He had noted at the time that the spots showed as " dark reddish brown circles with darker raised rings between." Mr. Staley had examined the fungus microscopically and identified it as a species of Septoria, but not having means for measuring the spores he was unable to determine their size. Shortly afterwards he sent specimens and in the letter accompanying them he wrote, " I am able to enclose a few leaves of the Shasta Daisy with the leaf spot disease. Most are from the upper part of the stem, the lower ones being already shrivelled, black, or dropped off. These are a few leaves with the large dead spots as I remember the disease, but most of them have smaller ones though most are showing fructifications."

The specimens sent to me by Mr. Staley showed symptoms similar to those on the plants at Bearsted and the same fungus was present in both cases. There seems no doubt from his description and his ready recognition of the disease that it was the same which he had found in 1915. It is certain, however, from a comparison of specimens from the two localities that in 1925 the disease occurred at Bearsted, Kent and at Hayling Island, Hampshire.

Although no inoculation experiments have been carried out yet to test its parasitism there is good reason for believing from the nature of the injuries caused and from the fact that many species of Septoria are known to cause leaf spots, that the fungus which is so constantly associated with the disease is the cause of the spotting and withering of the leaves. Assuming then that the disease is caused by a parasitic fungus it is obvious that to propagate from infected plants, by dividing up the rootstock, is unwise. Healthy plants only should be used for propagation. No attempts to control the disease by spraying have been attempted so far as I am aware, but with the somewhat similar disease on the varieties of *Chrysanthemum indicum* caused by *Septoria chrysanthemella* experiments have been carried out in America and the recommendations based on the experiments are to remove diseased leaves and then to spray the plants with Bordeaux Mixture. These measures would probably be effective in the present case.

Part IV.

Entomology.

FIELD EXPERIMENTS WITH DORMANT WINTER WASHES.*

By A. M. MASSEE.

Introduction.

In the autumn of 1924, East Malling was invited by Messrs. Tattersfield and Gimingham, of the Department of Insecticides and Fungicides at Rothamsted, to collaborate in testing in the field the toxicity of dinitro-o-cresol and its salts, together with other preparations to insect eggs. The insecticidal properties of these nitro compounds had been tested under laboratory conditions at Rothamsted, but suitable material was not available at or near Harpenden for testing their effect on the growing tree and on insect eggs under natural conditions.

Since the writer already had in hand a plan for elaborating, if possible, a more accurate method of measuring the effect of egg killing washes in the field, this proposal was welcomed as affording a much more promising basis of study than the testing of a number of proprietary articles of unknown ingredients.

Material Available.

Until the effects upon living plants of some of these possibly injurious oils were known, the choice of material had to be strictly limited, and trees had to be selected that were not required for further experimental work.

Fortunately there was available, on one of the pathological plots, a number of four-year-old plum rootstocks of known varieties, planted at two feet six inches apart and growing on their own roots. A few of each of these had been grafted with the variety Victoria. They had been allowed to grow naturally, so they were not particularly easy to spray efficiently, both owing to their proximity to one another, and to the thickness of their growth. One further disadvantage to this material was that it consisted of nine varieties planted in single rows, so that it was not a practical proposition to treat each variety with each spray fluid.

However, as will be pointed out later, this does not appear to have been a very important matter, since all the varieties of plum appeared to be equally heavily infected with aphis and to be equally resistant to spray damage at the period of application. Moreover, it was possible, with one exception, to arrange

* The main substance of this paper is reprinted from a joint contribution of the Rothamsted Experimental Station, and the East Malling Research Station, entitled, "A Quantitative Examination of the Toxicity of 3.5 Dinitro-o-Cresol and other Compounds, to Insect Eggs, under Laboratory and Field Conditions," by C. T. Gimingham, A. M. Massee and F. Tattersfield, published in the Annals of Applied Biology, Vol. XIII., No. 3, August, 1926.

the plots in such a manner that the majority included at least one or two of the Victoria trees already mentioned.

On the other hand, this material had certain very marked advantages. First, in other experiments with tar distillate washes, plums have been found to show susceptibility to damage, especially from spray application unduly delayed. If any damage had resulted, this material might also have been expected to show whether there were varietal differences in susceptibility.

In the second place this material was infested with a considerable number of eggs of Hop-Damson Aphis (*Phorodon humuli* Schr.), Red Spider (*Tetranychus telarius* L.)*, and a sprinkling of caterpillar eggs, in a season when, in our immediate vicinity, insect infections generally were notably scarce. For example, careful examination of a plot of young apple trees, especially planted for spraying trials, showed that eggs of apple aphids and Winter Moth were distinctly scarce, and that spraying of these trees would not have been worth while, because the number of insects present was not sufficient to do any appreciable damage.

This difficulty of finding the desired pest in quantity is most likely to be one of the recurring problems and trials of the economic entomologist, in trying out remedial measures in the field. He may plant plots of material very suitable for his special purposes, but unless he resorts to inducing artificial infections by direct methods in anticipation of his spraying programme he cannot be assured of getting the desired number of eggs, and he may have to travel far afield in his hunt for entomological material.

It was decided that the detailed observations should be mainly confined to the effects of these washes upon the eggs of the Hop-Damson Aphis (*Phorodon humuli* Schr.).

Examination both of individual shoots, and of each tree as a whole, indicated that the infestation of Hop-Damson Aphis eggs was very general. The distribution of infestation is illustrated in the table below.

TABLE I.

Illustrating distribution of Infestation of Hop-Damson Aphis (Phorodon humuli Schr.).

Variety.	No. of Shoots Examined.	Total No. of Aphis Eggs counted.	Average per Shoot.
Common Mussel	10	1173	117
Myrobolan B.	10	1346	135
Pershore	10	1392	139
Victoria	10	1192	119

* The Acarus on fruit trees is frequently referred to as The Common Red Spider (*Tetranychus telarius* L.) and the name is retained in this paper. At the time of writing the correct name of the species has not been decided.

Since the material available contained at least three species of Prunus, this general infestation is rather surprising, but it may be accounted for by the fact that the plot was in close proximity to a hop garden, from which the aphides may well have migrated during early autumn.

Field Methods of Judging Results of Sprays.

As already indicated, the especial interest of the writer in these experiments was the elaborating, under field conditions, of an accurate method of determining the comparative effects of these and similar washes.

The method generally used in the past has been to judge by general impression the amount of insect damage to each tree in the season following the application of the spray. This method of judging results had been tried during the previous season in preliminary spraying trials with similar washes and had been found unsatisfactory. Although "general impression" was valuable in determining the cleansing effect upon the tree, lack of spray injury, etc., it was of little use in affording any measurable data as to actual egg killing effects.

It was therefore decided to work out a system whereby an actual survey of the insect eggs could be made before spraying, and during the hatching season. By this means it was hoped to trace the actual effect of each wash on every individual egg examined.

Nevertheless the experience of the past season had taught that if such an inventory upon the actual egg population were to be undertaken, it must be carried out on a sufficiently large scale to allow for the probable interference of predaceous birds, insects, etc.

When the actual detailed examinations of the plum shoots began, a practical difficulty at once arose owing to the immense numbers of Hop-Damson Aphis eggs, which of course made a complete inventory impossible. Consequently, on each tree, shoots from twelve to eighteen inches in length were examined, and a single one selected which showed a "countable" number of eggs. This shoot was marked and as far as possible an inventory was made of the eggs on it. Since even on these selected shoots it was generally impossible to count all the eggs, it was necessary to take only those in recognizable places, e.g., in close proximity to the buds, on petiole scars, in cracks and wounds on the internodes, and on short spurs.

After spraying, daily examinations for hatchings were made both on sprayed and control trees. In order to facilitate this work, shoots adjacent to the selected ones were cut off the trees and examined in the laboratory from time to time.

These examinations showed that when approximately fifty-five per cent. of the aphis eggs on the unsprayed trees, had hatched, the rest (with few exceptions) had already shrivelled.

It was judged that this was the critical moment for a post-spray examination of the marked (inventoried) shoots, since if all the eggs capable of hatching on the control trees had hatched, those on the sprayed trees should have done the same.

All shoots on which eggs had been previously counted were now cut off and examined in the laboratory; in order to give the eggs on the sprayed shoots every opportunity to hatch, the shoots from the control trees were examined first.

Further, in order to give the eggs from the trees sprayed with different fluids an equal opportunity to hatch, single twigs from the whole series were examined on one day, and the process repeated until the whole series had been examined.

Although this precaution was taken, it was noted at the time that the percentages of eggs hatched were not materially higher on the later examined shoots. Hence it may be stated confidently that the normal hatching period was complete before the final examinations were undertaken.

During this second survey of the shoots, the chief points looked for were, first, the number of empty egg cases, from which aphids had hatched; and second, the unhatched or shrivelled eggs. As a matter of fact, there was little difficulty in distinguishing between the hatched and the shrivelled eggs, the final count being made, of course, by examination under the binoculars.

A pocket lens had to be relied on for the first inventory (made in the field). How closely these two inventories did correspond with one another a typical page from the record book shows on the opposite page.

The success or failure of such procedure must depend upon the certainty of being able to relocate the eggs. It must be quite obvious that it would be no easy matter to find small groups of eggs a second time unless they could be retraced by "landmarks." For this purpose, as already mentioned, buds, petiole scars, and cracks in the internodes were used. The counts of eggs always commenced at the bud nearest the base of the shoot, and each bud was taken in order up to the apex.

If the eggs around any one bud occurred in very large batches, they were not counted, but a reference was made in the field book noting their presence in quantity.

In order to make identification easier, all eggs recorded on petiole scars are indicated (as shown in the Table) by an asterisk, while those found in cracks or wounds are distinguished by a dagger.

Even by following these methods it was not anticipated that 100 per cent. of the eggs recorded at the first inventory would be accounted for, since it was more than likely that some casualties from unknown causes would take place.

TABLE II.

Illustrating Method of Recording Aphis Eggs on Individual Shoots and close correspondence of the two inventories.

(Page from Field Record Book.)

Pre-Spray Count in Plantation.		Final Post Spray examination in Laboratory.		
			Hatched.	Shrivelled.
Basal Bud ..	1		0	1
2nd ,, ..	*2		*1	*1
3rd ,, ..	7		3	4
4th ,, ..	5		2	3
5th ,, ..	*2		*1	*1
1st Lateral Shoot.		1st Lateral Shoot.		
Basal Bud ..	5		0	5
2nd ,, ..	1		0	1
3rd ,, ..	†4		†1	†3
4th ,, ..	1		0	1
5th ,, ..	3		0	3
2nd Lateral Shoot.		2nd Lateral Shoot.		
Basal Bud ..	2		2	0
2nd ,, ..	0		0	0
3rd ,, ..	1		0	1
4th ,, ..	1		1	0
3rd Lateral Shoot.		3rd Lateral Shoot.		
Basal Bud ..	6		3	3
2nd ,, ..	3		1	2
3rd ,, ..	†2		†0	†1
4th ,, ..	4		1	1
5th ,, ..	4		1	1
6th ,, ..	7		0	7
7th ,, ..	1		0	1
6th bud ..	10		4	6
4th Lateral Shoot.		4th Lateral Shoot.		
Basal Bud ..	4		1	3
2nd ,, ..	0		0	0
3rd ,, ..	0		0	0
4th ,, ..	0		0	0
5th ,, ..	2		0	2
6th ,, ..	1		0	1
7th ,, ..	1		1	0
8th ,, ..	0		0	0
5th Lateral Shoot.		5th Lateral Shoot.		
Basal Bud ..	10		5	5
2nd ,, ..	0		0	0
3rd ,, ..	4		0	4
4th ,, ..	0		0	0
5th ,, ..	0		0	0
6th ,, ..	0		0	0
7th bud ..	8		3	5
8th ,, ..	12		2	10
9th ,, ..	12		3	9
10th ,, ..	6		0	6
11th ,, ..	9		4	5
12th ,, ..	*4		*1	*3
13th ,, ..	6		2	4
14th ,, ..	8		4	4
15th ,, ..	5		0	5
Total originally noted ..	164	Total ultimately accounted for	47	112

In the particular instance given approximately three per cent. of the eggs could not be found at the second count. Over the whole survey the percentage of loss from unknown causes was actually 6 per cent. That this percentage is likely to vary from season to season and from experiment to experiment seems certain.

Since the question is bound to arise as to the mortality from natural causes, as well as the percentage of " unhatchable " eggs, the pre-spray count of eggs would appear to be amply justified.

It will be obvious that, in the winter of 1924-25 at any rate, this loss of eggs from unknown causes was not large enough to interfere seriously with the comparison of the proportions hatched on trees under the various treatments.

On very dull days, or when the shoots were wet, it was found impossible to count the eggs, so that this method has distinct limitations.

In addition to the detailed records on the selected shoots, general observations were recorded upon each tree. In this survey, quantity and species of eggs on the stems and stout shoots were noted, not individually, but generally. These general notes proved valuable later, since they confirmed the impression that the infection of the Hop-Damson Aphis eggs was generally widespread all over the plot.

It was possible, after selected shoots had been fully examined, to make a post-spray general survey of each plot. That survey showed Hop-Damson Aphis eggs to be hatching freely all over certain plots, whilst aphids were very scarce on others. By this means it was possible to confirm generally the effect of the sprays already measured on individual shoots.

A third general survey revealed the fact that certain species of eggs, for example, those of Red Spider, were not affected by the spray fluids.

It was also possible at the same time to get some idea of the cleansing properties of these washes, and some measure of the amount of damage to leaves and shoots caused by the Hop-Damson Aphis eggs which hatched.

Natural Mortality in the Field.

In order to measure the effects of the spray fluids accurately, it was essential first to arrive at the normal mortality of eggs on unsprayed trees. That this mortality will vary from season to season and under different conditions seems probable, in which case a detailed survey would have to be made for each individual experiment.

In this investigation, fifty-one convenient shoots (from forty-one unsprayed trees) were selected, and in all 9,446 eggs were counted and recorded.

The following Table shows the actual percentage of eggs which failed to hatch on each shoot.

TABLE III.

Natural Mortality in the Field.

Shoot No.	Per cent. of Recorded Eggs not Hatching.	Shoot No.	Per cent. of Recorded Eggs not Hatching.
1	49	27	49
2	45	28	47
3	31	29	45
4	46	30	48
5	48	31	43·5
6	17	32	42
7	45	33	44
8	46	34	44
9	46	35	44
10	46	36	48
11	48	37	47
12	48	38	43
13	49	39	48
14	46	40	47
15	44	41	42·5
16	44·5	42	44
17	48	43	46
18	40·5	44	47
19	47	45	46
20	46	46	44
21	47	47	45
22	49	48	45
23	46	49	48
24	50	50	46
25	48	51	47
26	44	—	—
			Average 45

It will be seen that with the exception of shoots three and six these percentages are amazingly uniform. Whilst the number of eggs per shoot for the whole series averaged 185, these two shoots had only forty-five and eighty-two eggs respectively, and the discrepancy is therefore less important than it appears.

This uniformity is further borne out by the probable error. This works out at ±.47, slightly over one per cent. of the mean.

In view of the measure of variability which has been obtained at East Malling in other field trials, this may be considered an unexpectedly encouraging result.

ARRANGEMENTS OF PLOTS.

Some details must be given as to the methods and conditions of spraying.

First, as to the arrangements of the plots. As already pointed out, the material included nine varieties of plum stocks growing on their own roots, and a number of worked Victorias scattered about the plots. The close proximity

of the trees, and the method of planting them in double rows, made the inclusion of every variety under each spray treatment impossible.

Of the 137 trees available forty-one were reserved as "controls." The majority of these were scattered in four large plots. There were in addition several isolated "control" trees.

With two exceptions, the sprayed plots each consisted of eight adjacent trees, arranged, as far as possible, to comprise two varieties of plum stock, and, in addition, at least one Victoria tree.

In three treatments only (namely Plots B., K. and P.) was it impossible to include a Victoria tree, and on a single Plot (P.) it was only possible to include one variety of rootstock (Pershore).

Since, from the chemical point of view, it seemed desirable to test as many sprays as possible, two of the less important fluids were allotted only four trees each. (Plots M. and P.)

A map is given on opposite page showing the distribution of these plots on the land, with the percentages of viable eggs killed on each of the sprayed plots.

The preparation of the spray fluids applied, and the details of their composition, are described in the joint contribution in the *Annals of Applied Biology*, already referred to.

Methods and Conditions of Spraying.

The growing conditions of the trees already described necessitated the use of spraying machinery, which could be easily handled amongst crowded trees. A hand manual spraying machine was therefore used. The spraying pressure obtained was from seventy-five to eighty lbs. to the square inch; since none of the trees was above ten feet in height this proved quite effective.

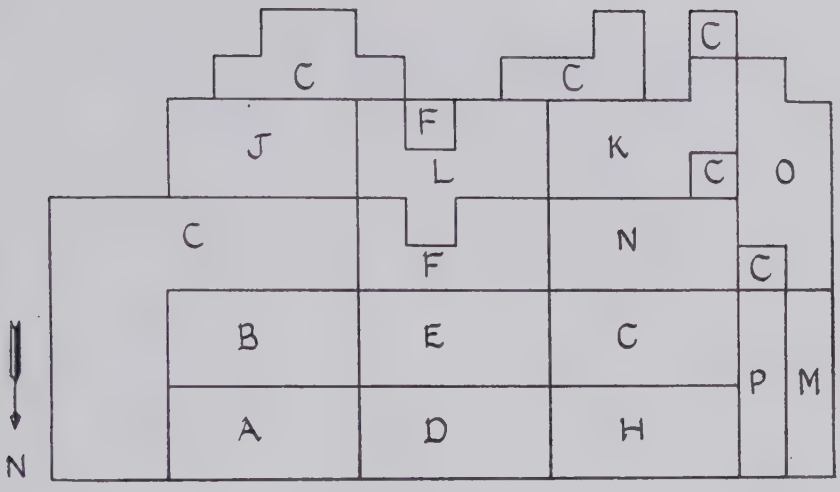
In order to guard against any of the sprays drifting from one plot to another, a screen of thick hessian cloth, nearly as high again as the trees, was placed round three sides of each tree during spraying, leaving the operator just room to work. This successfully prevented any serious drifting of the sprays.

All the sprays were applied on December 22nd, 1924.

The weather conditions on this day were admirable. Although it was cloudy in the morning, the sun subsequently appeared in the afternoon, and shone for three hours.

The following day, however, the conditions were not favourable; after two hours sun in the morning, it set in wet and half an inch of rain fell during the late afternoon and evening. Rain again fell in the following four days, and as much as .63 of an inch was recorded on the last of them.

It will be seen therefore that although the conditions were favourable on the actual date of spraying, the adverse weather which followed was probably detrimental to the effect of the sprays.



Arrangement of Plots.

The treatment of each plot can be ascertained by reference to the following key :

Plot	Treatment: Substance	%	Treatment: Solvent	%
A	Dinitro-o-cresol	0.25	High flash tar oil ..	2.5
B	,, ,, ...	0.5	,, ,, ..	5.0
C	Unsprayed Control			
D	Dinitro-o-cresol	0.35	Emulsified disinfectant	3.5
E	,, ,, ...	0.25	,, ,,	2.5
F	,, ,, ...	0.15	,, ,,	1.5
H	Sod. dinitro-o-cresylate	0.35*	Water (with 0.5% soap)	
J	None		Emulsified disinfectant	3.5
K	None		,, ,,	2.5
L	None		,, ,,	1.5
M	Chlordinitrobenzene ..	2.5	High flash tar oil ..	25.0
N	Emulsified heavy oil ..	7.5	None	
O	Proprietary tar distillate ..	7.5	None	
P	None		High flash tar oil ..	5.0

* Calculated as dinitro-cresol.

Very mild weather conditions prevailed during January, and in consequence some eggs began to hatch at this early date. The first record of eggs hatching on cut shoots in the laboratory was on January 9th. In the field, the first eggs hatched on January 19th. The eggs hatched mainly from the "control" shoots; but observations show that two of the sprayed plots (K. and N.) also showed hatchings at this early date.

Comparative Results of Different Sprays.

The methods employed of measuring the results of the spray fluids by an actual count of eggs has been fully described.

Table IV. gives all the details of the results.

TABLE IV.

Comparative Effectiveness of Different Sprays upon Eggs of Hop-Damson Aphis.

Plot	Treatment: Substance	%	Solvent	%	Total No. of eggs examined.	No. hatched.	No. not hatched.	Per cent. not hatched.	Per cent.* killed allowing for control.
C	Controls				9446	5171	4275	45	—
D	Dinitro-o-cresol ..	0.35	Emulsified disinfectant†	3.5	912	104	808	89	80
E	,, ,, ..	0.25	,, ,,	2.5	770	84	686	89	80
F	,, ,, ..	0.15	,, ,,	1.5	1049	117	932	89	80
J	None		,, ,,	3.5	918	453	465	51	11
K	None ..		,, ,,	2.5	975	651	324	33	Nil
L	None		,, ,,	1.5	1386	812	574	42	Nil
B	Dinitro-o-cresol ..	0.5	High flash tar oil ..	5.0	1147	110	1037	90	82
A	,, ,, ..	0.25	,, ,, ..	2.5	1423	136	1287	90	82
P	None		,, ,, ..	5.0	742	252	490	66	38
H	Sodium salt of dinitro-o-cresol (calcd. as D.N.C.) ..	0.35	Water with 0.5 (soap)		1246	1114	132	89	80
M	Chlordinitrobenzene	2.5	High flash tar oil ..	25	299	73	226	76	56
N	Emulsified heavy oil	7.5	None		974	533	441	45	Nil.
O	Proprietary tar distillate	7.5	None		1131	151	980	87	77

* The control figure has been allowed for in each case by deducting the average percentage which did not hatch on the control plots (45%) from the percentage not hatched on each sprayed plot and multiplying by $\frac{100}{100-45}$.

† This product was a proprietary article sold as a disinfectant.

Discussion of Results.

A reliably accurate control was obtained by examining a large number of eggs (9,446) on the untreated plots. The average figure for the mortality from natural causes was forty-five per cent. (cf. also Table III.), and only the remaining fifty-five per cent. can be considered in comparing the effects of the treatments. The figures given in the last column of Table IV. represent the percentage of "hatchable (viable) eggs killed," allowance being made for the natural mortality; they thus give a quantitative measure of the comparative efficiencies of the treatments under the conditions of the experiment.

Only the extreme differences can be regarded as of significance, but that these extremes are significant is shown by a study of the probable errors. It was only to be expected that the sprayed shoots would give a more variable hatch than the "control" shoots, since the evenness of the kill in the former cases is largely dependent upon the complete covering of the tree with the spray fluids, which again, is dependent upon the human element.

In the latter case, probably, the main cause of the kill is weather conditions, which might be expected to operate more uniformly. This greater variability on the sprayed shoots is actually found, yet, in spite of this, the probable error for eggs hatched on eleven shoots sprayed with fluid A is only ten per cent.

When the difference between the hatches on the "control" trees and those sprayed with fluid A is reckoned, it is found to amount to 43.8 ± 1.23; the difference therefore is over thirty-five times its probable error.

Since in this class of experiment a difference of 3.2 times its probable error is frequently considered significant, there need be no hesitation in accepting these extreme differences at least for these particular seasonal conditions.

Judged in the light of these criteria, the consistency of the results is encouraging.

The five plots (D, E, F, B and A) sprayed with fluids containing 3 : 5—dinitro-o-cresol, at concentrations ranging from 0.5 per cent. to 0.15 per cent., all show that from 80-82 per cent. of the viable eggs were killed. On the other hand, the solvents used in making up these spray fluids were tested alone on plots J, K, L and P, and found to have little or no toxic effect in themselves.

Sodium dinitro-o-cresylate, as used, also killed 80 per cent. of the viable eggs. The relative advantages of these different washes was discussed in the joint paper already referred to.

It is interesting to note that a proprietary tar distillate spray fluid—in Plot O, used at the strength recommended, also killed 77 per cent. of the viable eggs, a result of the same order as that given by the dinitro-cresol.

Two other materials were included in the trials. The emulsified heavy oil on Plot N was quite ineffective and the Chlordinitro benzene was only partially effective.

Red Spider (*Tetranychus telarius L*) eggs were numerous on all the plots. In the spring, frequent binocular and field examinations showed that the mites readily hatched out from their eggs on all plots, and were commonly seen on the trees throughout the summer. It can be definitely stated that none of the spray fluids used in this investigation had the least effect on red spider eggs.

It is interesting to note that one of the plum gall mites (*Eriophyes phlœocoptes Nal*) was found hibernating in quantity under the bud scales of many shoots. During the summer a survey of the plots was undertaken to collect some of these mites for another investigation. The mites were very scarce and could only be secured in reasonable numbers from the control plots. Hence it appears that the mites were probably killed by the sprays.

General Observations.

All the treatments showing a high efficiency against the eggs of the Hop Damson Aphis (plots A, B, D, E, F, H and O), also had a marked general cleansing effect upon the trees. All lichens and mosses on the trunks were killed and the bark thoroughly cleaned, giving the tree a healthy appearance. The " emulsified disinfectant " solvent alone at the two higher strengths—plots J and K—had a similar cleansing effect. None of the other plots showed any cleansing action.

During the following spring and summer field notes were made on the spread of the Hop-Damson Aphis on the trees.

In this respect the " control " trees could be readily picked out ; they were more severely damaged by aphis than the sprayed plots. Curled leaves were prevalent on all these trees, and the new growths were much stunted.

Plot K was markedly affected by aphis attack ; curled leaves were conspicuous, and many of the new growths were stunted.

Plots J, L and N were also severely attacked by Aphis, but the degree of infection was not so marked as on Plot K.

Aphids were commonly found throughout the spring on plots M and P. On these trees the infestation was not evenly distributed, some shoots being much more severely attacked than others ; nevertheless none of the trees was free from aphis.

The remaining Plots (A, B, D, E, F, H and O) were, with few exceptions, free from aphis throughout the summer. The few infections on these plots may be accounted for as follows :

It has already been stated that the trees on the plots were planted in close proximity to one another, and in some instances the branches, which had not been regulated by pruning, came in contact with branches of trees in adjacent rows. In those cases the aphids were observed to be migrating from plot to

plot; thus it was possible to find small colonies established on some of the trees on plots generally free from them.

Finally, a survey of the plots was made both before and after the blossoming of the plum trees, to ascertain whether the trees suffered as a result of the application of the sprays. These examinations showed that, with the exception of one tree, there was no apparent spray injury on any of the plots. This result is encouraging because plum trees are well known to be very susceptible to spray damage. It may be reasonably said that, if any of the sprays were likely to cause "spray injury" under completely dormant conditions, some injury would have been noticeable in this trial.

One tree on Plot M did look very unhealthy during the latter part of May. The leaves turned yellow, and the tree was defoliated early in the season. Whether this tree was injured as a result of the spray cannot be stated, although this is highly improbable. The remainder of the trees of this plot grew normally throughout the season.

The writer's acknowledgments and thanks are due to Mr. R. H. Le Pelley, for his assistance in carrying out these field experiments, particularly in connection with the laborious task of counting and recording the aphis eggs.

Conclusions.

The method adopted for obtaining quantitative data as to the egg-killing powers of different substances under field conditions has proved satisfactory.

It was possible, with the material available to compare the efficiency of the various treatments in the field with an accuracy comparable with that of the original laboratory experiments carried out at Rothamsted.

The results show the high insecticidal value of some of the substances being tested at Rothamsted, against the eggs of the Hop-Damson Aphis. Their general cleansing effect on the trees was also demonstrated.

TAR-DISTILLATE WASHES.*

THEIR COMPARATIVE EFFECTIVENESS, UNDER DIFFERENT CONDITIONS, ON VARIOUS PESTS, AND AT INCREASING CONCENTRATIONS.

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AND
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Introduction.

During the autumn of 1923, preliminary experiments with tar-distillate washes were undertaken with the dual object of testing a preparation of known composition alongside proprietary articles of this class, and of evolving a technique by which the toxicity of sprays to insect eggs under field conditions, could be more accurately ascertained.†

The use of tar-distillate or "Carbolineum" sprays for the washing of fruit trees in the dormant period of the year has extended very considerably and as the preparations on the market were all proprietary articles of unknown composition it seemed desirable that tests should be made with a preparation the origin of which was known. By this means it was hoped to obtain a tar-distillate wash made from well-known and easily procurable raw material which would give results as satisfactory as those found in the case of the best of the proprietary preparations.

In this connection it may be pointed out that owing to the variation in chemical composition of the tar-distillates it is impossible to lay down a strictly defined standard even though the raw material may be obtained always from the same source. The tar from which the distillates are obtained varies according to the method of preparation and the coal from which it is obtained and the process of distillation is conducted differently at the various works. The trade however distinguishes certain fractions of the distillation process by specific names such as "light oil," "creosote oil," "anthracene oil," and as these fractions have fairly well defined boiling points it is possible to suggest a formula upon which a wash may be prepared and to subsequently check its composition by chemical analysis.

Such a standard preparation could then be used in field trials and could be prepared if necessary by any maker or even by the grower himself if he were so minded and the method of emulsifying the oil on a small scale were found to present no special difficulties.

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† Annual Report, East Malling Research Station, pp. 143-4, 1924.

An examination of a number of proprietary tar-distillate washes led to the conclusion that whilst some of them contained materials other than those derived from coal tar, there was no reason to think that the efficiency of sprays of this class depended upon anything but the tar oils they contained.

Efficient emulsification is, of course essential both to enable the spray to be properly distributed and to minimize the risk of any damage to the tree or its buds.

It will be clear from what has been said above that a proprietary article of undeclared composition may vary considerably from time to time and although it may at one period prove satisfactory there is no guarantee that the same article will be supplied at another time. There is, further, no means of exercising any control of the nature of the material and both from the point of view of the experimenter who may be making trials and the commercial user of the article it seems very desirable that there should be some knowledge of the composition of the article that is being employed.

Owing to the scarcity of eggs in the neighbourhood during the winter of 1923-24, and to the subsequent disappearance of many of them, definite results could not be obtained with the technique employed. However, it was thought that under more favourable conditions, extended trials on these lines would be justified.

During the Winter of 1924-25, a survey of the material available was made, and, as eggs were present in somewhat greater numbers than in 1923, it was decided to continue the trials on a small scale.

The washes used in these trials were two proprietary articles and two tar-distillates prepared for the purpose by Messrs. Newton, Chambers & Co., Ltd., Thorncliffe Works, Sheffield.* The first of the two latter preparations (Standard A) was made from 75 per cent. commercial "light oil" containing 20 per cent. phenols, of specific gravity 1.016 having a range of boiling points as follows :

at	200°C.	13	per cent.
	220°C.	51	,,
	250°C. ..	78	,,
	300°C.	90	,,

Emulsification was by means of rosin and castor oil soap.

The second standard wash (B) was made similarly but with "anthracene or green oil" which had a specific gravity of 1.1 and a range of boiling points as follows :

at	220°C.	10	per cent.
	260°C.	20	,,
	300°C.	40	,,
	380°C.	60	,,

* It is desired to express our very best thanks to Messrs. Newton, Chambers & Co., for the great interest which they have shown in this question and to their chief chemist for invaluable suggestions and help in connection with the preparation of the above materials.

As the degree of emulsification of the tar-distillate washes may play an important part in their action, special attention was given to the manner in which all the washes behaved when mixed with water and when sprayed on to the trees.

It was found that all four washes mixed well with tap water forming milk-like emulsions with no separation of large globules of tar oil.

When the diluted spray was applied to the trees it was considered that one of the proprietary washes was slightly superior to the two standard washes in the manner in which it spread over the branches and stems whilst the standard washes in turn were superior to the other proprietary wash. No means of judging this point in the field was possible but the fact that all four preparations would be regarded as satisfactory indicates that efficient emulsification apparently presents no special difficulties.

No injury was noticed to the trees or buds but weeds under the trees were severely injured but not permanently killed.

For convenience the various tests carried out may be summarized as follows :

1. Comparative trial of proprietary and standardized tar-distillate washes on the eggs of the Hop-Damson Aphis., (*Phorodon humuli* Schrank) in the field.

2. Complementary test of the same proprietary and standardized tar-distillate washes on the eggs of the Hop-Damson Aphis; (*Phorodon humuli* Schrank) in the laboratory.

3. Test of a standardized tar-distillate wash on the eggs of the Winter Moth (*Cheimatobia brumata* L.), in the field.

4. Test of a standardized tar-distillate wash, at different strengths, on the eggs of the Vapourer Moth (*Notolophus antiquus* L.), in the laboratory.

1. Experiments on the Eggs of the Hop-Damson Aphis in the Field.

Material available.

For this trial there were available twenty six-year-old half-standard Black Bullace plum trees. The trees were planted 15 feet apart, and in one row, with the exception of five in another part of the plot which were set aside to be left unsprayed. Unfortunately, these latter proved to have too few eggs on them to justify their inclusion, so that seven Victoria plum trees, on another part of the ground, had to be substituted as the " controls " in this experiment.

Arrangement of Plot.

Of the fifteen trees in the row, numbers 2, 5, 8, 11, 14, were sprayed with Standard wash A.; trees 1, 4, 7, 10, 13 with Standard wash B.; and the remaining five with Proprietary wash C.

Methods of measuring Results of Sprays.

A preliminary survey of the one year shoots was made, and those showing the largest number of eggs were labelled for detailed counts. These marked shoots averaged three per tree.

In January, a pre-spray count of eggs was made on the selected shoots. The numbers of eggs near each bud and in cracks in the internodes were recorded in relation to such "landmarks," so that they might be located again in a post-spray survey. The pre-spray inventory was made in the field with a pocket-lens.

For some weeks before the post-spray examination was made, shoots from the sprayed trees were examined until it was evident that the hatching period was complete. The selected shoots, on which the pre-spray count had been made, were then cut from the trees and the final examination was made between April 4th and 7th. This examination was made in the laboratory with a binocular microscope. The hatched eggs are readily detected by the typical split in the egg, made by the insect in emergence.

Application of Sprays.

The spray was applied on January 23rd, 1925, by means of a hand-manual machine, at a pressure of 75-80 lbs. per square inch. To prevent any possible drifting of spray, trees were protected by a screen made of hessian cloth.

The two standard washes, and the proprietary wash were used at the strength of $7\frac{1}{2}$ gallons of wash to $92\frac{1}{2}$ gallons of water. This was the strength recommended by the manufacturers of the proprietary wash used. The proprietary wash was bought for commercial spraying from the manufacturer's local agent.

The weather conditions were good. There was a slight breeze, but no rain fell till the 26th. There were about four hours sunshine, during the day.

Comparative results of sprays.

The figures obtained as a result of the different treatments are shown in Table I.

TABLE I.

Toxicity of tar-distillate washes to the eggs of the Hop-Damson Aphis in the field.

Treatment.	Number of eggs recorded.	Hatched.	% hatched.	% reduction in hatching.	% viable eggs killed.
Unsprayed	712	392	55	—	—
Standard A. ..	676	245	36	19	35
Standard B. ..	355	114	32	23	42
Proprietary C. ..	407	119	29	26	47

The first three columns are self-explanatory. The normal hatch, on "controls" being 55 per cent., each spray is seen to cause a reduction in the percentage of eggs hatching, as shown in column 4. The percentage of eggs which may be considered as killed by the wash is obtained by calculating the reduction in hatching as a percentage of the normal hatch. For example out of 100 eggs treated with Standard wash A., 36 hatched. But the number which hatched on untreated trees shows that only 55 of this hundred were viable. This indicates that 19 out of 55 viable eggs were killed, that is 35 per cent. The percentages of viable eggs killed, so calculated, are shown in column 5.

General conclusions.

Owing to the scarcity of eggs present, and to the low percentage normally hatching on unsprayed trees, it is not possible to form definite conclusions on the relative efficacy of the different sprays in a single season. It is evident from the high percentage of eggs hatched on the sprayed trees (column 3), that, under the conditions of the experiment, none of the washes used was an efficient control for the pest. This was borne out by later observations which showed both sprayed and control trees slightly infested by the aphis in June.

Finally, there was no evidence of spray damage on any of the trees; these were examined periodically during and after the blossoming period.

2.—Complementary Experiments with the Same Washes on the Eggs of the Hop-Damson Aphis, in the Laboratory.

In the autumn of 1924, it was decided to supplement these field experiments, as it was known that these eggs hatched freely on cut shoots kept under indoor conditions, during the winter, in water or water-culture.

A hedge of Myrobolan B plum, heavily infested with eggs, provided excellent material for the trial, and it was realised that the detailed counts of eggs, could be undertaken indoors when rain and poor light made it impossible to record eggs in the field. Finally, it was desired to test whether the normal hatch varied under artificial and natural conditions.

Cut shoots of Myrobolan B, about 12 inches long, which bore sufficient eggs were selected for the experiment. In all 144 shoots were used. The shoots were graded according to size, and representative samples of twelve were placed in each of twelve jam jars, six of which contained water and six a water culture solution. Two jars were used for each of four treatments, the remaining four jars being left as unsprayed "controls." This gave twenty-four shoots for each treatment and forty-eight for "controls."

Method of Recording Eggs.

An exact pre-spray inventory of the eggs on the shoots was made under a binocular microscope. The number of apparently sound and also of shrivelled

eggs, near each bud and on the internodes was recorded. In each case the count began at the apical bud and continued to the tenth bud from the apex. The variety of Prunus used was particularly suitable because the black eggs showed up distinctly on the green shoots. The pre-spray record was made during the third week in December.

Daily observations were made to determine the first date of hatching, which proved to be January 9th. At this date the post-spray survey began, and periodical records of hatching were made on all shoots, with the binocular microscope. These examinations were made nearly every day from January 9th to February 14th. Only those eggs showing the typical split made by the aphis on emergence were counted as hatched.

Application of Washes.

The three washes used in the field experiment—Standard A, Standard B, Proprietary C—together with another Proprietary tar-distillate (labelled Proprietary D), were used in this laboratory trial. These were used at the strength of $7\frac{1}{2}$ parts of wash to $92\frac{1}{2}$ parts of water. They were not applied with a machine but each shoot was immersed in the spray fluid for about ten seconds. They were allowed to dry before being replaced in the jars. This application was made on December 23rd, 1924.

Comparative Results of Sprays.

The figures obtained are shown in Table 2.

TABLE 2.

Toxicity of tar-distillate washes to the eggs of the Hop-Damson Aphis, in the laboratory.

Treatment.	Apparently sound.	Naturally shrivelled.	Hatched.	% hatched of apparently sound.	% reduction.	% viable eggs killed.
Unsprayed "Controls"	260	104	202	78	—	—
	234	81	154	66		
	231	91	187	81		
	159	174	120	75		
				75		
Standard A...	283	114	99	35	42	56
	243	127	73	30		
				33		
Standard B...	257	121	47	18	58	77
	232	177	35	15		
				17		
*Proprietary C.	229	111	46	20	51	68
	254	127	68	27		
				24		
*Proprietary D.	215	101	44	20	52	69
	216	78	53	25		
				23		

* Proprietary C. and D. were commercial samples of "Carbo Krimp" and "Mortegg" respectively, *as supplied during the season of* 1925.

The first column of figures gives the number of eggs which were apparently normal; the second column, the number which before spraying were shrivelled or shrunken. These shrivelled eggs were not expected to hatch and are not generally included in the calculations. It occurred however that thirteen of these eggs (less than 1 per cent.) did hatch. These have been included in the figures of column 1.

Referring to the table, it will be seen that the hatch on the "control" shoots was 75 per cent. In this season, therefore, it is an interesting fact that the hatch on controls was 25 per cent higher under artificial conditions than it was in the field. It should be mentioned that the "control" hatch in the field was found to be fairly constantly 55 per cent., on several varieties of plum, and with a large number of eggs, in another series of experiments also. How far such a difference is likely to vary from year to year remains to be shown.

The eggs which hatched on the sprayed shoots, in this laboratory test, varied from 17 per cent. to 33 per cent. The viable eggs killed (calculated as explained in the account of the previous experiment) varied from 56 per cent. to 77 per cent.

It is interesting to compare the results of Tables 1 and 2. Although the percentages of sprayed eggs hatching, indoors and out, are closely similar (17 to 33 per cent. indoors; 29 to 36 per cent. out) the percentages of viable eggs killed are considerably higher indoors (56 to 77 per cent. indoors; 35 to 47 per cent. out). This is explained by the fact mentioned above, that the normal hatch was higher indoors. Thus whilst it is possible to make comparative trials of washes in the laboratory, it would appear that care must be taken in thus gauging their actual degree of toxicity in the field.

3.—Experiments with the Eggs of the Winter Moth in the Field.

Since little accurate information as to the effect of tar-distillates on Winter Moth eggs, in this country, was available, it was decided to test one of these washes on a small scale, in the field.

Thirteen bush apple trees of four varieties were available for this trial.

Methods of measuring Results of Sprays.

Owing to the scarcity of eggs and to the fact that they were widely scattered about the branches, it was impossible to select representative shoots for recording, as in the previous experiments. A thorough examination was made of each tree, and the position of each egg observed was marked with a small tag label, tied on the shoot just above or below the egg. This was done during the first week in January.

Periodical examinations were made, and, a week after hatching had ceased on the unsprayed trees, the post-spray examination was made. This continued from May 4th to the 6th. Both examinations were made with a pocket lens. It was

not anticipated that every egg labelled in the first count would be re-located in the final examination. It occurred in the final inventory that the average number of eggs per tree, not traced was almost identical on sprayed and "control" trees. Twenty eggs were not located on five "control" trees, and thirty-one were not found on eight sprayed trees. These were therefore not included in the calculations.

Application of Spray.

The spray used was the tar-distillate hitherto referred to as "Standard A." It was applied at the strength of $7\frac{1}{2}$ gallons of wash to $92\frac{1}{2}$ gallons of water. The trees were sprayed on January 14th, commercially, by a power sprayer.

The results obtained are shown in Table 3.

TABLE 3.

Toxicity of a tar-distillate wash to the eggs of the Winter Moth, in the field.

Treatment.	Eggs labelled.	Hatched.		Reduction.	Viable eggs killed.
Unsprayed "controls"	40	35	95%	—	—
	33	33			
	21	20			
	21	20			
	25	25			
	140	133			
Standard A. $7\frac{1}{2}$ in $92\frac{1}{2}$	21	1	15%	80%	84%
	9	1			
	28	5			
	14	3			
	17	6			
	18	5			
	40	2			
	14	1			
	161	24			

The first three columns of the table are self-explanatory, and the percentage of viable eggs killed is calculated by the method previously described.

The figures show how the percentage hatch on "controls" affects the percentage of viable eggs killed. Although the hatch on sprayed trees is as high as 15 per cent., the percentage of viable eggs killed is 84. This result seems to warrant a repetition of the trial with the same wash.

Spray injury was not observed on any of the trees.

4. Experiments to Test Various Strengths of Tar-Distillate Washes on the Eggs of the Vapourer Moth, in the Laboratory.

The question of the most efficacious and at the same time economical strength of tar-distillate, seemed of sufficient importance to justify a comparative

experiment in the laboratory, and as Vapourer Moth eggs were obtainable from a neighbouring orchard, it was decided to carry out a preliminary trial.

Systematic collecting in a commercial bush apple plantation, was undertaken, and Vapourer Moth egg batches were carefully removed from the trees. This occupied three days in January 1925, and, as a result, 122 batches were found. Owing to other work more time could not be spent in this search.

The egg batches were placed on filter paper in Petri dishes, ten batches in each. The Petri dishes were placed on wooden boards and surrounded by tree-banding grease to prevent the escape of the caterpillars as they hatched. They were kept in the laboratory.

Application of Sprays.

The spray selected was the tar-distillate " Standard B ". The following Table shows the various strengths used and the detailed arrangement of the experiment.

Designation of Treatment.	Strength of Spray.	Number of batches used.
I.	7½ to 92½	30
II.	0 to 100	30
III.	10 to 90	20
IV.	5 to 95	10
V.	3 to 97	10
VI.	15 to 85	5
VII.	20 to 80	17 (some small)

The egg batches were removed from the dishes and were sprayed by means of an atomiser. The spray was applied on February 12th. The following day, the batches were replaced in the Petri dishes, and, from that time until hatching, sprayed and " control " batches were lightly damped with tap water once a week.

Methods of Measuring Results of Sprays.

Daily observations for hatching were made. The first date of hatching was March 17th, and, after this date, with few exceptions, the hatched larvæ were removed twice daily, and their numbers recorded from each treatment. The tree-banding grease effectively prevented migration of the hatched larvæ from one dish of treated batches to another. Thus it was possible to obtain an exact figure for the hatch resulting from each treatment.

During the observations of hatchings, it was found that some of the batches were partially parasitized by a minute Scelionid (*Telenomus dalmanii* Ratz.).* The parasite flies readily so it was not possible to record the number hatching as was done in the case of the Vapourer larvæ. However, in every case in which the parasite was observed while emerging, it was seen to do so through the side

* We are indebted to Dr. James Waterston for the identification of this insect.

or bottom of the egg. The Vapourer Moth larva, on the contrary invariably hatched from the top of the egg.

In a number of cases, after having bitten a hole in the egg, and sometimes partially extruded itself, the larva was unable to free itself completely from the egg shell. The numbers of these have been recorded in the column headed "Dead before total emergence."

The last date of hatching was May 25th. It will be seen therefore that the hatching period extended over more than two months. Some weeks after the last date of hatching each egg was examined with the binocular microscope, the difference in hatching between Vapourer larvæ and Scelionid parasite making it easy to ascertain the number of these latter in the final count. The number of unhatched eggs was also recorded.

The figures obtained in this test are summarized in Table 4.

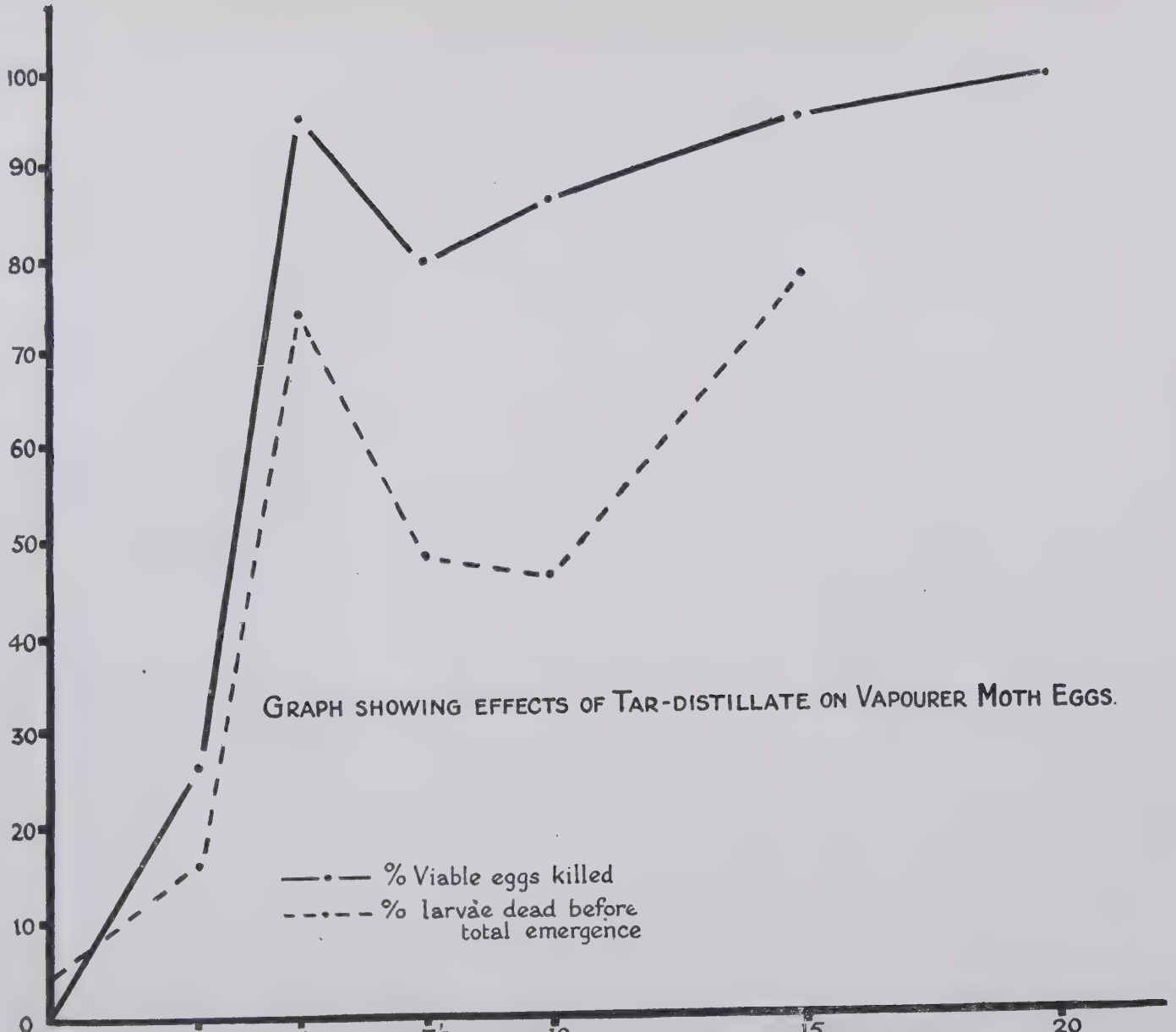
TABLE 4.

Comparative effectiveness of different strengths of a tar-distillate wash against Vapourer Moth eggs, in the laboratory.

Treatment.	Strength.	Total Counted.	Hatched.	Not Hatched.		Eggs Parasitized.	% hatched of total.	% reduction.	% viable eggs killed.
				Not Hatched.	Dead before total emergence.				
II. ..	0	8616	4874	2686	187	869	57	—	—
V. ..	3	2523	1055	1147	217	104	42	15	26
IV...	5	2967	92	2611	264	—	3	54	95
I. ..	7½	8058	982	6183	891	2	12	45	79
III.	10	5309	435	4489	375	10	8	49	86
VI.	15	1062	35	835	125	67	3	54	95
VII.	20	2210	10	2191	8	1	0.5	56.5	99

It will be seen that the percentage hatch in each case is calculated on the total number of eggs used in the treatment. The parasitized eggs are included in the total. It will be realised that the percentage hatch would be higher in the "control" series and some of the other treatments if it had been calculated on the number of eggs not parasitized.

The table shows that, with the exception of treatment IV (5 per cent.) the percentage of viable eggs killed rises with the concentration of the spray, from 26 per cent. in treatment V (3 per cent.) to 99 per cent. in VII (20 per cent.). At present no explanation can be offered for the high kill by Treatment IV, the exception referred to, but it is probably due to some, as yet untraced, source of error. A repetition of this experiment, including the strength 5 per cent.



GRAPH SHOWING EFFECTS OF TAR-DISTILLATE ON VAPOURER MOTH EGGS.

on a larger number of eggs, is being undertaken in 1926 to learn whether these indications are really significant.

The two strengths usually recommended for commercial spraying, namely $7\frac{1}{2}$ per cent. and 10 per cent. are thus seen to have killed respectively 79 and 86 per cent. of the viable eggs.

It is interesting to notice that of the total number of eggs known to contain larvæ (i.e., the sum of the columns "Hatched" and "Dead before total emergence"), the percentage of those dead before total emergence rises with the concentration of the spray, very similarly to the rise in the percentage of viable eggs killed. The foregoing graph shows two curves, 1, the percentage of viable eggs killed, 2, the percentage of larvæ dead before total emergence, both plotted against rise in concentration of the spray.

The similarity of the two curves is apparent. The unexpected feature of a disproportionately high kill at 5 per cent., illustrated in the first curve, is paralleled in the second curve by a similar high percentage of larvæ dead before total emergence.

Summary.

1. In preliminary trials in the field, against Hop-Damson Aphis, tar-distillate washes of known composition, did not prove superior to a proprietary article. None of the washes however proved sufficiently toxic under the conditions described.

2. In similar trials, under laboratory conditions, the washes appeared much more toxic. It was noticeable that a much higher normal hatch was also obtained on shoots indoors.

3. Some information was obtained as to the effectiveness of a tar-distillate wash against Winter Moth eggs in the field. At $7\frac{1}{2}$ per cent. the results were encouraging.

4. Preliminary indications suggest that although higher concentrations of tar-distillate may slightly increase the actual efficiency, probably the optimum strength lies between 5 and 10 per cent.

5. The experiments indicate the possibilities of evolving a fairly accurate technique for measuring the efficiency of egg killing washes in the field.

EXPERIMENTS IN THE TRANSMISSION OF "REVERSION*" IN BLACK CURRANTS.

By J. AMOS, R. G. HATTON, R. C. KNIGHT and A. M. MASSEE.

Introduction.

Reversion has for some years been recognised as a definite disease of black currants which has involved considerable economic loss. Although the trouble is frequently associated with infestation by the big-bud mite, the relationship between the two has never been satisfactorily elucidated. An otherwise clear correlation is confused by the occurrence of bushes which are badly reverted without showing the symptoms of mite infestation, and even of bushes showing severe mite attack but no apparent reversion. Further it has been impossible to discover any constant relationship between the severity of the mite attack and the intensity of the symptoms of reversion.

In view of these facts, experiments along several lines were initiated in 1921 in order to investigate the following questions :—

I. Whether direct infection of normal plants with mites was followed by the development of the symptoms of reversion, and if so, to what extent quantitative correlation existed.

II. (*a*) Whether reversion could be communicated from plant to plant across a vegetative union.

(*b*) Whether the disease is likely to be transmitted by the knife during pruning operations.

(*c*) Whether the disease is perpetuated through the seed.

III. (*a*) Whether reversion could be induced by disturbance of the normal metabolism of the plant.

(*b*) Whether it was possible, by transference of sap, to carry the disease from one individual to another.

* The use of the term "Reversion" is in no way intended to signify a return of the plant to the wild form. In this paper it is employed in conformation with its common usage by growers, and subsequently, by experimenters, to denote a particular well-known set of growth characteristics. A separate paper, "Reversion" of Black Currants, I., "Symptoms and Diagnosis of the Disease," by J. Amos and R. G. Hatton is appearing in the *Journal of Pomology and Horticultural Science*, Vol. VI., No. 3.

I. DIRECT MITE INFECTION.

By A. M. Massee.

Methods of Obtaining Direct Infections.

In 1921, a preliminary experiment was undertaken in the laboratory to ascertain whether it was possible to transfer living mites from one bud to another, without killing them in the process.

As far as the writer is aware, very little has been published on this subject, but one reference appears to be of interest. Swanton (I.) in his treatise on "British Plant Galls" remarks that "Peyritsch published in 1888 some very interesting observations concerning experimental production of galls by placing mites on various plants." (Species unknown.)

It was fully appreciated that the methods adopted for transferring the mites would necessarily be of a very delicate nature, and that since no description of technique was available, various methods of transferring the mites from one bud to another would have to be tested.

The fact that, at the time of normal migration and natural infection of new buds, the colonies of mites are rapidly dispersing and the individuals are not readily collected or kept under control, made it inadvisable to attempt transfers during this period. Therefore the transfers were mainly carried out between October and March, when the mites were concentrated in the buds and easily collected. It is fully realised that manipulations at this abnormal period may have accounted for the irregularity with which successful infection was achieved.

Method I.

In the original attempt, a batch of black currant cuttings, each about twelve inches long, was selected from bushes free from big-bud and placed in glass jars, containing about three inches of moist silver sand. The cuttings were fumigated with hydro-cyanic-acid gas as a general precaution, and were afterwards kept in the laboratory.

Swollen buds inhabited by gall mites were collected, and were cut up into small pieces with a razor. Portions of the buds containing large quantities of mites were selected, and were wedged between the buds and the stems of the cuttings. The object was to find out whether the mites would migrate of their own accord from the drying galls on to the healthy buds on the cuttings. This procedure was repeated many times, over a period of three weeks.

From time to time, examinations were made with the binocular microscope to determine the movements of the mites, and it soon became evident that the small pieces of galls quickly dried out, and the mites perished before they could enter the healthy buds. As a result of these observations, the above method was not proceeded with.

Since this initial attempt, it has become more and more evident that the mites, at certain stages in their life-cycle, will not survive any length of time when exposed to daylight. This is very apparent in the autumn, when they are normally in the centre of the buds. The only time during which they appear to be able to withstand daylight is in the spring, when they normally migrate from their winter quarters, the old drying up big-buds, and continue their life-cycle on the open bush.

METHOD II.

A number of big-buds were selected, bisected, and examined under a binocular microscope.

When a bud was found to contain a considerable quantity of mites, a healthy shoot was brought into close proximity to it, and an attempt was made, with a camel-hair brush, to transfer the mites to the outer bud scales on the healthy cutting.

Later, however, detailed examinations indicated that the delicate mites did not survive this treatment.

METHOD III.

Galled buds were cut up into small pieces with a razor and examined under a binocular microscope, and those containing the greatest number of mites were picked out. These were immediately placed in a small light-proof cardboard box. After some hours under these conditions, the mites within the box became very active, and moved about freely on the portions of buds, their activity varying with temperature. Experience has shown that this period of activity is the best time for their transference.

Considerable difficulty was however experienced in obtaining a suitable instrument for transferring the mites. A fine setting needle, a camel hair brush, and a very fine bristle were tried in turn, but, for various reasons, they proved to be unsuitable.

Finally, a slender human hair, fixed in a wooden handle, was found to be satisfactory. It was observed that as soon as the fine hair was brought into close contact with the chosen mite, the latter attached itself to the hair, where it remained for a considerable time.

Since 1922, this method of transference has been used in all direct infection experiments.

Before actually placing the mites on the healthy buds, it was found desirable to tease open one or two of the outer bud scales. The hair with the mite attached was then placed just under the bud scale and, immediately this was done, the mite left the hair and attached itself to the bud-scale. These inoculations are carried out most easily with the aid of a binocular microscope.

After some considerable practice it was possible to transfer the mites without difficulty, and the direct infections of the healthy buds could even be made without the assistance of a binocular microscope.

Having demonstrated that it was possible to transfer living mites successfully by the method described above, it remained to test how long they survived the operation, and whether it was possible to apply it on a sufficiently large scale to make inoculation experiments reliable.

Whilst carrying out tests on this larger scale it was found that, in order to secure the successful establishment of a colony of mites in a healthy bud, it was necessary to transfer a large number. If only four or five individuals were transferred they generally lived for a short while and then perished without reproducing, but if considerable numbers are transferred the colonies usually survived.

A possible explanation of this result was provided during a more detailed examination of the mites, which revealed the fact that fully 98 per cent. are females. Indeed, males are scarcely ever detected, and, consequently, four or five mites selected at random and transferred to an otherwise mite-free bud may very easily all be unfertilised females which naturally fail to produce a colony.

Preliminary Trial of the Method on a Single Plant.

In September, 1921, a potted plant of the variety Baldwin, free from symptoms of bud-mite and reversion, was selected and brought into the laboratory.

It consisted of two main shoots branching near the soil level, and at the outset these two shoots were separated by means of a piece of cardboard, covered on both sides with tree-banding grease, placed vertically between them. The shoots were separated in this way in order that one branch might be subjected to direct mite inoculation, and the other kept mite-free.

A disc of cardboard which had a small hole cut in the centre, to allow the stem of the plant to pass through, was also fixed in a horizontal position at the base of the stem, resting on the rim of the pot. The space between the stem and the card was plugged with cotton wool, in order to prevent mites or insects passing from the soil to the plant. This barrier also was covered with grease.

The plant was fumigated with hydro-cyanic acid gas, and the treatment was repeated four days later.

The first direct mite transfers were made at the beginning of November, 1921. Each bud of the shoot was inoculated and, as far as possible, the same number of mites were placed on each. At the same time, the scales of the buds on the control shoot were slightly moved with a needle in order that their condition, except for the presence of mites, might be similar to that of the buds on the inoculated shoot.

The process of transference was repeated at weekly intervals until the end of April, 1922, in order to establish large colonies of mites within the buds. However, the frequent transfers resulted in such a heavy infestation that many of the buds dried out completely, causing the mites in them to perish.

This phenomenon also appears to occur in the field (4). A bush severely infested with mite is frequently observed to have many small dried up buds upon it. These dead buds in all probability, have been destroyed by the mites which were present in numbers far too great to be supported by them.

The inoculations were resumed on the new growth in the autumn of 1922, but in this season they were carried out only once a month instead of weekly, as previously, in order to reduce the intensity of the infestation.

During the spring and summer months the control shoot of the plant was sprayed with a nicotine wash, about every ten days, which kept aphides and other insects in check.

Only one big-bud developed on the mite infected shoot up to the end of April, 1922, though all the basal buds had completely dried up, and many of the buds near the centre of the shoot were small and malformed.

By March, 1923, three big-buds had formed near the top of the shoot, all the other buds having dried up. By June, 1923, the whole of the inoculated shoot had become reverted, and, as may be seen in Figure 1, none of the lower buds had made any growth. The control shoot remained normal throughout 1922 and 1923. It was evident, however, that the attempt to keep this shoot free from mites was not successful after the second year. Although, the shoot was making normal growth, the lower buds dried out similarly to those of the inoculated shoot, and in the spring of 1924 big-buds appeared. Finally, during that summer the whole bush became reverted.

The result of this experiment was encouraging. First, it clearly demonstrated that it is possible to inoculate bushes with living colonies of mites on a reasonably large scale.

Second, the appearance of reversion subsequent to the inoculations suggested that experiments on a larger scale might give reliable evidence concerning the relationship existing between the two diseases.

Main Infection Trials.

Two series of direct infection trials were carried out upon two distinct batches of plants.

Material.

The primary object in selecting material was to obtain plants as free as possible both from latent reversion and from mite infestation.

The most suitable material available was a collection of Baldwin Black Currant Seedlings, which were the progeny resulting from the "selfing" of a

known Baldwin bush. The seedlings had been raised in comparative isolation from infected bushes.

In order to attain this practical certainty of freedom from mite infection and reversion, a certain measure of uniformity had to be sacrificed. The seedlings often possessed individual characteristics, although generally speaking seedlings of Baldwin " selfed " approximate closely to the parent. The use of seedlings, however, was considered at the time the lesser of two evils, although the results to be discussed later seem to suggest that their individuality may in some measure account for the variability of the results of the inoculations.

At the commencement of the experiment all the plants were one year old and were grown in 9 inch pots so that they could easily be transferred to the laboratory for manipulation.

The mites used for inoculation were obtained from an adjacent commercial plantation, owing to the scarcity of material on the Research Station. Since, naturally, no records had been taken upon the bushes in this plantation, and since the material was not obtained until after leaf fall, it was not possible to be sure whether the mites came from normal or reverted bushes or branches, and the only precaution possible was to obtain material from a single bush for each complete batch of inoculations.

On the other hand, the following summer revealed the fact that all the bushes in the row were in part reverted. It can, therefore, with considerable confidence, be assumed that the material used was obtained, at least in the vast majority of cases, from reverted branches or bushes.

Since at this stage it was becoming increasingly likely that the mites were carriers rather than actual causes of the disease, an attempt was made in the second series of inoculations to discriminate between mites from reverted and non-reverted bushes. Unfortunately, after the first season's inoculations had been carried through, the normal (but mite-infested), bush, which served as source of material, developed reversion, and all the mites for the subsequent season's inoculations had their origin from obviously reverted bushes.

In consequence of this fact, although some of the plants infected with mites from this apparently normal bush developed reversion in the first season, it is unsafe to conclude that mite attack *per se* was responsible for producing the disease.

Treatment of Control Plants.

In each series of transfers there were approximately twenty-four untreated (control) plants.

Throughout, in order to keep the control plants as free from mite infestation as possible, they were grouped together and not inter-mixed with the inoculated series. However, they were planted adjacent to them to ensure their growing under similar conditions.

The control plants were fumigated with hydro-cyanic acid gas monthly as before during their dormant season. Each year, in March or April, according to the season, they were sprayed with a delayed dormant lime-sulphur wash, at a strength of one in thirteen. During the spring and summer months, the plants were sprayed once or twice weekly, as necessary, with a solution of nicotine and soft soap.

Throughout the winter the bushes were kept under a small lean-to glass frame, and in the summer they were plunged in the open ground. The controls of the second series remained in the ground permanently from 1924 onwards.

The bushes were not cut back or pruned, but, in order to encourage growth, each received a dressing of fish guano in spring. The bushes also received a top dressing of rich new soil each winter.

The control plants were carried into the laboratory while the transfers upon the complementary series were in progress. This precaution was taken to ensure similarity of conditions, including temperature, etc., throughout.

Finally, at the time of the transfers, as before, the bud scales of the control plants were raised with a needle, in order that their treatment might be similar to that of the buds on the infected plants.

The Direct Transfers.

There were twenty-four plants in each series subjected to mite transference. The bushes in both series were fumigated with hydro-cyanic acid gas previous to their being directly infected with mites.

In view of the fact that spraying operations could not be carried out on these plants, owing to the possibility of destroying mites that were established on them, the plants were frequently examined during the spring and summer months, and all insects removed from them by hand.

In order to facilitate the transfer work, the plants were removed to the laboratory or greenhouse.

In the first series, a transfer was made on March 28th, 1922, and further transfers were made monthly from October to March, 1922-23, and again during the same months of 1923-24. A similar scheme was adopted for the second series a year later. Inoculations of individual plants were in the main discontinued after colonies of mites had obviously become established.

Finally, in 1925-26 two bushes in the second series were once more inoculated with mites, the plants in question not having developed big-buds previously.

Behaviour of the Inoculated Series.

The observations made upon the bushes inoculated with mites are summarised in Tables I. and II.

Table I.

Inoculated Bushes of First Series.

Bush No.	No. of Big-Buds.		Degree of Reversion.	
	1922–23.	1923–24.	1923.	1924.
4	0	0	Nil.	Nil.
8	0	0	Nil.	Nil.
15	0	6	Nil.	Nil.
3	3	14	Nil.	Nil.
16	1	2	Reverted.	4B.
11	1	0	,,	1C.
17	1	6	,,	2D.
7	1	2	,,	5D.
10	2	6	,,	5D.
13	0	1	Nil.	1E.
1	1	1	Reverted.	1E.
12	1	0	,,	1E.
19	2	3	,,	2E.
6	0	1	,,	4E.
5	0	1	,,	4E.
21	2	13	,,	5E.
9	1	1	,,	5E.
20	0	2	,,	5E.
2	0	10	,,	5E.
18	2	14	,,	5E.
14	3	28	,,	5E.

Table II.

Inoculated Bushes of Second Series.

Bush No.	No. of Big-Buds.			Degree of Reversion.		
	1923–4.	1924–5.	1925–6.	1924.	1925.	1926.
1	3	8	8	Nil.	5C.	5E.
3	17	74	129	1E.	1E.	1E.
5	1	4	18	Nil.	Nil.	1E.
7	10	14	17	Nil.	3D.	5D.
9	5	60	81	Nil.	5E.	5E.
11	1	7	14	Nil.	4C.	4C.
13	1	3	7	3E.	5E.	5E.
15	6	15	0	Nil.	5C.	5D.
17	0	10	15	Nil.	1D.	1E.
19	3	17	40	4D.	5D.	5E.
21	0	1	57	Nil.	Nil.	5C.
23	4	6	4	Nil.	3C.	5C.
25	1	1	16	Nil.	Nil.	Nil.
27	0	9	2	Nil.	5D.	5D.
29	0	13	55	Nil.	4D.	5D.
31	0	0	27	Nil.	Nil.	1E.
33	2	13	0	Nil.	3C.	5C.
35	7	14	14	Nil.	4E.	4E.
37	3	4	65	1E.	1E.	3E.
39	3	1	6	Nil.	Nil.	Nil.
41	5	15	2	4E.	5E.	5E.

For some years past in estimating the amount and intensity of reversion exhibited by a bush, a system of numerals and letters has been adopted. The numerals represent the number of fifths of the bush which is attacked, and the lettering the intensity of the symptoms. A, B, C, D, and E represent increasing degrees of abnormality, the last being the extreme. This notation is adopted in these tables. Throughout the observations, only typically swollen buds were recorded as big-buds.

In the two series of inoculated bushes forty of the forty-two bushes developed big-buds to a greater or less extent during the first or second season or both. In thirty-six of these cases where colonies of mites had become established severe symptoms of reversion have appeared. In four cases it has not done so. There is no obvious explanation why these four bushes have resisted the disease. It is possible that as individuals they possessed a higher degree of immunity. Similar cases are from time to time reported in the field.

In any case, the correlation between this resistance or the actual degree of reversion, and the amount of mite attack as measured by a count of big-buds, seems to be at most irregular.

In Table I. the bushes are arranged in the order of the degree of reversion recorded, but this does not correspond at all exactly with the total number of big-buds counted. Compare, for instance, bushes Nos. 3 and 18, or 1 and 9 in First Series. On the other hand bushes Nos. 21, 2, 18 and 14 are the most severely big budded and are " 5E " cases of Reversion.

Similar observations could be made upon Table II., but in view of the fact that the history of each individual colony cannot be followed out in detail, no reliable conclusion can be drawn as to this aspect. Once again, this lack of direct correlation between the obvious intensity of big-bud attack and the degree of reversion is very patent in the field. Moreover, the appearance of reversion is recorded at very varying intervals from the first appearance of big-bud. Whilst on the initial bush and in the first series the symptoms of reversion appeared comparatively rapidly in the majority of cases, only a small minority of the bushes in Series 2 showed the symptoms within fifteen months of the recorded appearance of mite.

However, it may be questioned if a close quantitative correlation or a constant chronological relation would be expected if reversion were a virus disease.

Behaviour of the " Control " Bushes.

The observations made upon the Control Bushes in both series are summarised in Tables III. and IV.

In the two series of controls, thirty-five bushes out of a total of forty-three developed no big-buds and showed no symptoms of reversion. Three other bushes

TABLE III.

Control Bushes of First Series.

Bush No.	No. of Big-Buds.		Degree of Reversion.	
	1922–23.	1923–24.	1923.	1924.
24 to 29 and 31 to 45	0	0	Nil.	Nil.
30	0	0	5E.	5E.

TABLE IV.

Control Bushes of Second Series.

Bush No.	No. of Big-Buds.			Degree of Reversion.		
	1923-4.	1924–5.	1925–6.	1924.	1925.	1926.
2, 4, 6, 8, 10, 12, 18, 20, 22, 24, 32, 34, 36, 42	0	0	0	Nil.	Nil.	Nil.
16	0	0	0	Nil.	Nil.	5D.
26	0	0	0	Nil.	Nil.	5C.
14	0	0	1	Nil.	Nil.	Nil.
28	0	0	1	Nil.	Nil.	Nil.
30	0	0	34	Nil.	Nil.	Nil.
38	0	0	1	Nil.	Nil,	Nil.
40	0	0	12	Nil.	Nil.	Nil.

showed reversion, one at the first examination in 1923 and the others at the third examination in 1926. No obvious big-buds were produced on the three bushes, but in one of them, No. 30, Series I., at any rate, a new species of non-big-bud-forming mite was found to be present,* when the bush was examined under a binocular microscope for big-bud mite.

The remaining five bushes belonging to Series II., showed no reversion in 1926 but had developed big-buds the previous winter, perhaps owing to the fact that the lime sulphur spraying had been discontinued the year previously.

II. TRANSMISSION THROUGH CONTACT OR VEGETATIVE UNION.

By J. AMOS AND R. G. HATTON.

A series of experiments has been designed and carried out to test the possibility of transmitting reversion either through the organic union of normal and diseased plants, or even as a result of temporary contact between normal and diseased material.

* This new mite has been fully described by Nalepa (2) and experiments are in progress to ascertain whether there is any correlation between its attack and reversion.

Transmission of Reversion by Grafting and Inarching.

In the summer of 1921 a number of one year old Black Currant bushes (variety, French Black) of known parentage, were examined for reversion. Twenty normal and twelve reverted bushes were selected, none of which showed any apparent big bud. On March (15th), 1922, ten of the normal bushes were each grafted with a single reverted scion taken from a known reverted bush of the same variety. The individual buds of all the shoots cut from these normal stocks were examined by A. M. Massee for mite, and declared free. The other ten normal bushes were simply left ungrafted as " controls "—five being cut back and five left unpruned.

Two years later—i.e., in the summer of 1924—all these controls were still normal. In the ten plants grafted with reverted scions, unfortunately nine of the grafts died out very rapidly the same season. Only one survived. The suckers which had in the meantime arisen from the originally normal stock which bore this graft possessed typical reverted foliage in the summer of 1923, suggesting that reversion had been transmitted to it from the still living scion. Of the other nine stocks, only five survived for examination. Whilst four of these remained normal, one became reverted during 1923. This suggested that it was at least possible that in this case the graft had survived sufficiently long to transmit the trouble, although actual union had not taken place.

Six of the twelve reverted bushes received normal grafts—the other six being left as controls, but unfortunately not a single one of the normal grafts survived. It was therefore decided to repeat the experiment on a larger scale in succeeding seasons and to carry out the grafting when the material was in a more dormant stage. Henceforward the grafting proved much more successful and the majority of the scions grew away healthily. It was also decided to attempt the less drastic method of " inarching " normal and reverted bushes, in case the grafts should again fail.

In 1923, units of nine bushes (or combinations of bushes) were treated in the following ways on February 28th :

9 normal scions were whip grafted on normal stocks (as controls).
9 normal scions were whip grafted on reverted stocks.
9 reverted scions were whip grafted on normal stocks.
9 normal bushes were inarched with normal bushes (as controls).
9 reverted bushes were inarched with normal bushes.

Tables V. and VI. summarise the results of all the surviving combinations made during 1923 and 1924.

From the figures for the 1923 series as shown in Tables V. and VI., it will be noted that in no instance was the transmission of reversion apparent during the first season (i.e., that immediately following grafting), but that in all cases it appeared in the spring of the second season.

TABLE V.

Transmission of Reversion Across a Vegetative Union.

Grafting.

Series No.	Time of Grafting.	Diagnosis Previous to grafting of:		No. of Scions alive.	Diagnosis in Season following grafting.				Diagnosis in Second Season.				No. of Successful Transmissions.
		Stocks	Scions		Stocks		Scions		Stocks		Scions		
					N.	R.	N.	R.	N.	R.	N.	R.	
1	28th February, 1923	N.	N.	4	4	0	4	0	4	0	4	0	Nil.
2	,,	R.	N.	2	0	2	2	0	0	2	0	2	2 out of 2
3	,,	N.	R.	6	6	0	0	6	0	6	0	6	6 out of 6
4	3rd March, 1924	R.	N.	40	0	40	40	0	0	40	0	40	40 out of 40
5	,,	N.	R.	33	33	0	0	33	0	33	0	33	31 out of 31

R Reverted. N=Normal.

TABLE VI.

Transmission of Reversion Across a Vegetative Union.

Inarching.

Series No.	Time of Inarching.	Diagnosis Previous to Inarching.	No. of Pairs.	Season following Inarching. 1923.		Second Season. 1924.		No. of Successful Transmissions.
				N.	R.	N.	R.	
6	28th February, 1923	All N.	9	17	1*	16	2*	in 1 case out of 9*
7	,,	One N. and one R. in each Pair.	9	9	9	0	18	in 9 cases out of 9
8	3rd March, 1924	,, ,,	12	12	12	0	24	in 12 cases out of 12

R = Reverted. N = Normal.

* One plant originally diagnosed as normal reverted suddenly in the season in which the inarching was performed, in the succeeding season it transmitted reversion to the plant with which it was inarched.

Only two of the nine normal scions grafted upon reverted stocks survived, but both these showed typical reversion in the spring of 1924. Of the nine reverted grafts placed upon normal stocks, six lived. In all six cases the stocks upon which these grew sent up reverted suckers in 1924.

Four of the Control Series (Normal on Normal) survived, and all remained normal.

In the inarching experiments (i.e., grafting by approach, a method which is clearly shown in figure 4), where normal and reverted plants had been united, all nine of the reverted bushes and all nine of the normal ones survived. In 1924 all the nine normal units became reverted. The nine pairs of control (normal) bushes also survived and, with a single exception, remained normal. In the same season as the inarching took place, one of a pair of these bushes showed typical reversion (which doubtless came from some outside source). This combination was the exception which proved the rule, for in 1924 the normal partner of this reverted unit showed typical symptoms of reversion.

By the summer of 1924, therefore, the evidence for the theory of transmission by vegetative union was exceedingly strong, but in order to place it beyond question, a still larger unit of plants had already been grafted and inarched in that spring.

Forty normal scions were grafted on reverted stocks, and all survived. In the summer of 1925, all the grafts which were previously normal produced reverted shoots (see fig. 2).

Thirty-three reverted grafts survived on thirty-three normal stocks, and all thirty-three stocks produced reverted suckers (see fig. 3).

Finally, the twelve normal bushes inarched with reverted partners, all reverted in 1925 (see fig. 4). In all, then, 103 successful transmissions were made, whilst with the one exception that proved the rule, all the controls remained healthy (see fig. 5).

All these experiments were conducted in the open, the variety French was used throughout, and the reverted scions and stocks were all "advanced" cases. As a result, the transmission was in every case well marked, though not always equally extreme in all cases. False reversion was quite common the first year where the grafting operations forced immature buds into growth.

A small series of soft wood graftings, six reverted scions on normal and six normal on reverted, were also carried out on pot plants under glass in June, 1924. All the grafts grew readily, and in every case reversion appeared in the previously normal portion in 1925.

During the three seasons there were fifteen cases in which reverted scions came into contact with normal stocks but failed to establish any visible organic union themselves. In nine of these cases the normal stocks showed reversion the following season, in the other six cases the stocks remained normal.

Subsequent Development of Big-Bud.

It has already been stated that both the stocks and grafts—normal and reverted—were selected with special reference to their apparent freedom from mite attack, and wherever practicable the material was microscopically examined for its presence. Nevertheless it was decided not to discard the material immediately the primary object had been attained, but to keep it under further observation.

The results of these subsequent examinations were as follows :

In the 1924 series, out of seventeen cases in which normal units (grafts, stocks or inarched plants) became reverted, presumably through contact or union with diseased units, none of the normal portions manifested big-bud either at the time of their use, or at the end of the first growing season or, indeed, *until after the symptoms of reversion had been noted* in July, 1924. However, in eight out of these seventeen cases, the artificially reverted units showed *big-bud at the end of the season in which they had manifested the reversion symptoms* for the first time, and by the end of the third growing season (from the grafting) all seventeen units were heavily infested with big-bud. The behaviour of the seventeen complementary reverted units in this 1923 series is hardly less puzzling. Though they were marked and selected for use because they showed reversion without manifesting the presence of big-bud, by the end of the first season, i.e., that in which the union had taken place, ten of them showed big-bud. By the end of the second growing season, fifteen out of seventeen showed it, and by the end of the third season from grafting, they were all heavily infested. On the other hand ninety per cent. of the units in the inarched series *remaining normal* at the end of the third season also manifested severe big-bud infection.

In the much larger series in 1924 the position was very similar and almost as irregular, though in that year a few of the normal units (approx. ten per cent.) did actually show slight big-bud *previous to manifesting* the symptoms of reversion, and subsequently, in the second year after grafting, the general attack of big-bud on the plot was very severe. Indeed the situation of the plot—in the big-bud and reversion corner—unfortunately lent itself to the rapid spread of the former, at least, and no attempt to control it was made. However, in the inarched series, not one of the twelve normal units showed big-bud previous to the manifestation of reversion, and only a single big-bud was recorded on their reverted companions, though, in the second season, one of nine surviving bushes originally normal showed big-bud, as did also three of the reverted units.

Such severe attacks of big-bud occurring in the year following signs of reversion are, of course, only too common in the field, but our present information does not enable us to be sure whether the mites were present in the buds or on the bushes before they manifested themselves.

In the pot experiments under glass, unfortunately detailed records are lacking, but it is at least certain that the majority of the plants did not show big-bud at the end of the second season.

A further series of grafting experiments have now been carried out, with a view to excluding the possibility of mites being transferred upon reverted grafts because their presence cannot be detected in unswollen buds. Pieces of reverted shoots from which all buds have been removed are being used as stocks and intermediate grafts. The grafting operations have been successful and the plants are being kept under controlled conditions, but they cannot yield their result before the publication of this progress report.

Transmission Through Seed.

From 1921 onwards attempts have been made to discover whether reversion is transmissible through seed, but the difficulty has been to obtain seed which would germinate. As Table VII. shows, in five cases, flower trusses upon reverted bushes were "selfed," and, although seed was obtained in three out of the five cases, only two seeds have germinated. One, a 1924 seedling, is undoubtedly normal, but the second, a 1925 one, is as yet too small to permit of diagnosis. In the single case where two reverted plants were crossed (French ♀, Baldwin ♂) none of the six seeds germinated.

In five cases pollen from normal bushes has been placed on reverted flowers, but, again, although seeds have been produced there has been no germination. On the other hand, in three cases, pollen from reverted bushes of French and Victoria, has been placed on normal flowers of Baldwin, and in each case much seed has been produced and a considerable number of seedlings have survived. It has already been possible to establish the fact that nineteen of these have produced normal seedlings. The rest are as yet too young for examination. It has been suggested that bees might carry reversion by pollen, but we have no record that the three bushes so pollinated became reverted.

Transmission by Pruning Knife.

Finally, a series of cuttings were set aside for the purpose of seeing what evidence could be obtained of the spread of reversion by the pruning knife.

Pairs of cuttings—two reverted followed by two normal cuttings—were planted in considerable number in February, 1924. They grew poorly, but were all cut hard-back in succession in March, 1925, so that each pair of normal bushes would be cut immediately after each pair of reverted ones, with the same unsterilised knife.

In October, 1925, 136 originally normal bushes were still alive, and still normal as was to be expected. In the following spring, forty-three of these adjacent normal and reverted bushes were cut down for the second time, but the

TABLE VII.

Experiments on Transmission of Reversion through Seed.

Date.	Female Parent.		Male Parent.		Seed Produced.	Seed Germinated.	Condition of Seedlings.
	Reverted.	Healthy.	Reverted.	Healthy.			
1921	French	—	—	French	much	none	—
1921	French	—	open flowers	open flowers	much	4	Normal
1922	French	—	own pollen	—	none	—	—
1924	French	—	own pollen	—	16	1	Normal
1922	French	—	—	Baldwin	much	none	—
1924	French	—	—	Baldwin	20	none	—
1924	French	—	Baldwin	—	6	none	—
1919	—	Baldwin	Victoria	—	much	13	10 survive—Normal
1922	—	Baldwin	French	—	much	9	Normal
1924	—	Baldwin	French	—	100	35	Apparently Normal (small plants)
1924	Baldwin	—	—	French	none	—	—
1924	Baldwin	—	own pollen	—	15	none	—
1925	Baldwin	—	own pollen	—	50	1	Too small to say
1921	Victoria	—	own pollen	—	none	—	—
1921	Victoria	—	—	Baldwin	much	none	—

rest of the bushes were allowed to go untouched. By June of this season (1926) eight of the forty-three normal plants showed reversion. Of the previously normal series, which remained uncut for second season, it was only possible to examine thirty-seven. Of these eleven showed reversion. Unfortunately, all the plants were attacked severely by aphis during 1926, and, further, big-bud once more became very prevalent, so that it is not possible to argue confidently that even the cases quoted were one of transmission by the knife. The experiment is being repeated, with every effort to obtain better controlled conditions.

A plantation of 670 Black Currant bushes, all of which have been kept under close observation for six years, affords no general indication of the spread of reversion along the rows from North to South, the direction in which they were annually pruned. On the other hand, there are similar rows which have become reverted from end to end—100 per cent.—which have never been touched with a pruning knife after the initial cutting down at planting.

The writers would like to express their thanks to Mr. A. W. Witt for his assistance in the work of grafting and inarching.

III. PHYSIOLOGICAL ASPECT.

By R. C. Knight.

Some experiments on the physiological aspect of reversion have been conducted during recent years. The problem may be shortly stated as follows: Reversion, whether it be of functional or organic nature, is the morphological expression of physiological abnormality, and a study of the comparative physiology of normal and reverted plants may provide some information concerning this correlation. A small series of experiments has been carried out in this connection and these are reported elsewhere in this volume.

If reversion is a purely functional disease, it appears possible that the condition might be induced *de novo* by a disorganisation of the normal metabolism of the plant, by the introduction of substances calculated to disturb the existing equilibria. Experiments on these lines, which are described below, have failed to induce reversion, but the range of substances and concentrations used has been necessarily small.

Attempts have also been made to transmit reversion from abnormal to normal plants by transference of sap obtained by exudation during periods of high root pressure. These trials, in contrast to those described under Section II. above, involved no organic union between the normal and reverted individuals, the sap being transferred either directly or indirectly through glass and rubber connections.

"STEM-FEEDING" EXPERIMENTS.

(*a*) Attempts were made to produce the characteristic morphological symptoms of reversion by introducing into the plants various substances calculated to bring about a disturbance of the normal metabolism. Normal two- and three-year old bushes which had been under observation from the time of planting as cuttings, were used for the experiments, and two methods of introducing the selected substances were used. At first, one year old stems were pierced with a needle and woollen threads were drawn through. The ends of the threads, which acted as wicks, rested in a reservoir of liquid below, and the liquid passed up the wicks into the stem (see fig. 6). It was found that in dry weather the wicks tended to dry out, and also the pierced stem soon healed around the wick so that only very small quantities of liquid entered the stem. Further, on account of evaporation from the wick it was not possible to be sure of either quantity or concentration of the solution actually entering the stem. This method was therefore abandoned in favour of one in which closer control was possible. In April or May, a one year old shoot of the plant was cut down to within two or three inches of the parent branch and a glass tube was attached to it by means of rubber, the cut surface being kept wet meanwhile. The solutions to be introduced into the plant were placed in the tube and the transpirational activity of the remaining leafy portions of the bush caused the absorption of the liquid into the cut stem (see fig. 6). The quantity of the liquid absorbed was measured daily and when the rate of absorption became very low the cut stump was pared in order to expose a fresh surface, and the tube refitted. By this means, absorption was kept going as long as twenty-five days, and as much as 40 cc. of liquid was taken in through the cut stem. The plants were kept under observation during the following two or three seasons.

The tables below indicate the scope of the experiments.

1922. Thirty potted plants were used and divided into series as follows:

Series.	No. of Plants.	Method of Supply.	Solution used.
1	3	None	None
2	3	Wool wicks	None
3	6	,, ,,	Water
4	6	,, ,,	2 % Cane Sugar
5	6	Glass tube	10 % ,, ,,
6	6	,, ,,	0.5% Oxalic acid.

In none of these cases was any plant afterwards found reverted. One shoot of a plant in series 2 was marked "suspect" but on examination immediately before the experiment the same plant had been similarly marked. Large portions of the plants in series 6 were killed and the new growth which developed

late in the season from buds low down on the stems showed the well-known distortion of the first-formed leaves (false reversion).

1923. Thirty plants in the field. Glass tube method throughout. Treatment between April 6th and May 11th.

Series.	No. of Plants.	Solution used.	Average vol. absorbed per Plant.
1	6	None	
2	6	Water	43 cc.
3	6	5% Cane Sugar	19 cc.
4	6	0.5% Sodium Bicarbonate	27 cc.
5	6	0.1% Boric Acid	13 cc.

Examination in July, 1923, and July, 1924, disclosed only one shoot in series 4 showing slight reversion, but it is very doubtful whether such an isolated case as this can be attributed to the treatment to which the plant was subjected.

The plants treated with boric acid reacted in a manner quite similar to that observed in the oxalic acid treated plants in 1922.

1924. Thirty-six plants in the field. Glass tube method throughout. Treatment between May 27th and June 8th.

Series.	No. of Plants.	Solution used.	Average vol. absorbed per plant.
1	6	None	—
2	6	Water	20 cc.
3	6	5 % Cane Sugar	21 cc.
4	6	1 % Sodium Bicarbonate	38 cc.
5	6	0.05 % Boric Acid	38 cc.
6	9	1 % Potassium Nitrate	40 cc.

No reversion was detected in any of these plants in 1924.

In July, 1925, one plant of series 5 was definitely reverted, but as in the 1923 case, the evidence is not sufficiently conclusive definitely to attribute the result to the treatment.

(*b*) In addition to the introduction of solutions of pure substances by stem absorption, normal plants were supplied with liquid obtained from reverted plants. Several of the latter were cut to within two inches of ground level in April or May, every shoot being removed. A bent glass tube was attached to each stump and was made to deliver into a glass reservoir which was lightly covered with soil to screen from bright light and to prevent undue rise of temperature.

Root pressure action resulted in exudation of liquid from the cut-back stems, and as much as 40 cc. of exudate has been obtained in a day from a two-year-old plant, although usually the quantity is about 20 cc. The liquid collected in the reservoirs was transferred daily to tubes attached to normal plants in the manner described in the previous series of experiments.

1922.

Six normal potted plants were supplied with exudate from reverted plants. Only a small quantity of the liquid was absorbed between May 29th and June 4th. No reversion appeared in these plants in 1922 or 1923.

1924.

Six normal plants in the field were supplied with exudate from reverted plants between May 29th and June 6th. The average volume absorbed was 19 cc. No reversion appeared in either 1924 or 1925.

Both these series of experiments were run at the same time as the similar ones with pure solutions described above, so that the control series for the latter also acted as controls for the former.

It was observed that the exudate obtained by the action of root pressure from pruned plants (whether normal or reverted) in the manner described above, was practically clear at the outset, but became opalescent in a few hours. An attempt was therefore made to transfer the exudate directly from one plant to another before the advent of the changes which produced the opalescence in the liquid. Pairs of plants growing close together were selected for this purpose, each pair consisting of a normal and a reverted plant. One stem of the normal plant was cut back as for "stem feeding," as described above, and all the stems of the reverted plant were removed, as for the collection of exudate. One stump of the latter was then connected with the cut-back stem of the normal plant, by means of a narrow-bore glass tube filled with water (see fig. 6). Exudate was collected from the remaining stumps of the reverted plants. The two plants were left thus connected together for four or five weeks. Small air bubbles appeared at intervals in the connecting tube and when this occurred the tube was refilled with water and the connection re-established. When the connection had been found broken on three successive days the experiment was stopped.

There was no means, by the method used, of determining the quantity of liquid passing from plant to plant. The reverted plant was known to be exerting root pressure from the fact that its other cut stems were exuding sap. Further, thirty or forty normal plants treated similarly to those in the experiment were absorbing various liquids more or less rapidly so that it is practically certain that exudate from the reverted plant passed into the normal one.

1922.

Two pairs of plants used.
One normal plant showed the usual false reversion in new shoots arising from the pruned stem late in the 1922 season. No reversion appeared in 1923.

1923.

Seven pairs of normal and reverted plants were used and three pairs, each consisting of two normal plants, were connected as controls. The three normal plants cut completely down showed the normal distortion of new foliage in 1923. No reversion appeared in either 1923 or 1924.

1924.

Six pairs of normal with reverted and three pairs of normal with normal were set up. No reversion appeared in 1924 or 1925.

Thus it has not been found possible, by the introduction of foreign substances into the plant to induce the symptoms of reversion in normal plants. The range of substances employed however, was necessarily very narrow.

The transference to normal plants of liquid exuded by root pressure from reverted plants has also failed to induce reversion.

Discussion.

I.—Examination of the results of the experimental infection of normal plants with big-bud mite, reveals some outstanding facts concerning the relationship between mite infestation and reversion. Tables III. and IV. show that with three exceptions, all the forty-three control plants remained normal throughout the experiment. Every endeavour was made to keep these control plants free from the attacks of big-bud mite and other insects. Subsequent examination showed that these measures met with very considerable success, though big-bud mite was ultimately detected on five of the controls. However, on one of the three plants in this series which developed reversion, a new species of mite was found to be present.

On the other hand, inoculation of bushes with big-bud mites, resulted in the establishment sooner or later of active colonies on forty out of forty-two cases. Of these forty successfully inoculated plants, thirty-six subsequently showed reversion. These facts, considered alone, appear to establish a definite correlation experimentally demonstrated between bid-bud mite and reversion. There were, however, four cases in which big-bud mite was successfully established on the plant but reversion has not as yet supervened.

Further, it is evident from the tables that when a comparatively heavy attack of mite is manifest, it is not invariably followed by relatively severe symptoms of reversion, and conversely when the mite infestation is apparently slight, extreme reversion may follow.

These exceptional cases, together with the apparent lack of quantitative correlation, still remain to be explained. It must be emphasised, however, that the plants selected for these experiments were, for technical reasons already stated, seedlings, so that different individuals may have possessed different degrees of susceptibility to mite attack and to reversion. Further, although each plant was subjected to a similar number of inoculations, which were as far as possible of similar intensity, the colonies became established on the different plants at different times. Nothing, therefore, is more likely than that at any one period of the growth of the plants, the intensity of infection, as indicated by the number of big-buds developed, was very variable. Indeed the tables show that the number of big-buds ultimately recorded varied from 1 to 120. It will be obvious from these remarks that, even under experimental conditions, it is extremely difficult to control and regulate the intensity of infestation by an organism of the nature of the big-bud mite, and, even when infection is established it is equally difficult accurately to measure the degree of the attack.

Incidentally, these carefully controlled experiments provide confirmation of the conclusion already arrived at from field observations, namely, that the control of big-bud mite by lime-sulphur spraying has been accompanied by a very considerale reduction in the amount of reversion.

II. and III.—If, in the Grafting and Inarching experiments, observations on the plants had been discontinued as soon as reversion appeared, the definite conclusion could have been drawn that reversion was readily transmissible by vegetative union or direct contact. In 103 cases where normal and reverted individuals were successfully united (i.e., where the graft or inarched pair lived) reversion regularly appeared in the normal partner to the union, after an interval of one growing season. Out of another fifteen cases in which the reverted graft failed during the first season, nine of the normal stocks still developed reversion in the second season. Further, of these 112 cases of transmission, only nine showed any symptom of big-bud infestation prior to the appearance of reversion. However, as detailed above, in the vast majority of cases, more or less severe attacks of big-bud mite appeared on the out-door plants *subsequent* to the manifestation of reversion, either at the end of the second season after grafting, or at latest by the end of the third season. Although, here and there, a big-bud appeared contemporaneously upon the normal control pairs, it cannot be claimed that the infestation was anything like so marked.

Whilst it may be suggested that this big-bud attack was a subsequent unrelated phenomenon of extraneous origin—(especially in view of the behaviour

of the indoor plants)—the writers do not feel justified in ignoring the possibility of a prior mite infestation which did not show itself externally in the usual ways.

Whilst it seems more than probable that the transmission of reversion by a sufficient period of direct contact is possible, the presence of big-bud mite as a disturbing factor must first be entirely eliminated.

Suspension of final judgment is perhaps also indicated by the failure to transmit reversion by sap transfusion, although it should be emphasised that the conditions in an experiment involving transference of sap by the methods described above are fundamentally different from those in grafting and inarching trials, since in the former, there is no organic continuity between the two plants concerned. In the experiments in Section III. the sap is exuded from the cut stem of one plant and is transferred mechanically to the stem of another, whereas when the two plants are grafted or inarched, not only is there a transference from xylem to xylem, but, in addition, interchange of material is possible through the union of other tissues of the two individuals. The possibility of the transmission of reversion by such means cannot at present be excluded, but it is realised that in nine out of fifteen cases where grafts and stocks failed to unite, reversion nevertheless appeared in the absence of organic union.

In the successful grafting and inarching experiments, the contact between normal and abnormal individuals was direct and continuous. Thus in the grafted plants, the quantity of liquid transmitted from reverted stock to normal scion must have been greatly in excess of that passing over in the experiments in Section III. In the latter, moreover, the transfer was not direct, and the opalescence which has been observed in sap exuded from the cut stems (3, p. 30) may have involved fundamental changes in the character of the liquid.

The fact that no definite evidence has been obtained in these experiments of the ready transfer of reversion, as, for example, by means of a pruning knife, lends support to the suggestion that the liquid may change its character soon after its removal from the tissues.

The writers have great pleasure in expressing their indebtedness to Dr. G. H. Pethybridge, who, during the preparation of this paper, has rendered invaluable aid by his sustained interest and stimulating criticism and comments.

Summary.

1. Ninety per cent. of normal black currant bushes developed reversion sooner or later after successful artificial infection with big-bud mites.

2. Ninety-two per cent. of normal bushes (controls) in which big-bud did not appear, developed no reversion symptoms.

3. Reversion appeared in three bushes on the absence of big-buds.

4. Big-buds appeared in five bushes unaccompanied by reversion.

5. There is very little relation between the number of visible big-buds and the intensity of accompanying reversion symptoms.

6. Reversion has appeared in 100 per cent. of previously normal individuals grafted to or inarched with reverted plants.

7. In these cases the symptoms appear after a lapse of one season following the grafting or inarching operation.

8. The evidence is strong, but not conclusive, that transmission of reversion in these cases was independent of big-bud mites.

9. It has not been possible to induce reversion by metabolic disturbance, nor to transmit the disease by sap transfusion.

10. It has not yet been possible to demonstrate the transmission of reversion through the seed.

11. The evidence obtained indicates that the disease is not regularly nor easily transmitted by the pruning knife.

References.

(1) *Swanton, E. W.* (1912). British Plant Galls.

(2) *Nalepa, A.* (1924). Marcellia, XXI., 95-96.

(3) *Priestley, J. H., and Wormall, A.* On the Solutes Exuded by Root Pressure from Vines. New Phyt., 1925, 14, 24-38.

(4) *Lees, A. H.* Big-Bud. Annual Report, Horticultural Research Station, Long Ashton, 1919.

FIG. 1.
Showing left—a Mite-infected and Reverted Shoot. Right—a Normal Shoot. Big-Bud not present.

FIG. 2.
Two originally normal Shoots grafted upon " Reverted " Stock, February, 1924. Both show true " Reversion," June, 1925.

FIG. 3.
Two " Reverted " Shoots grafted upon Normal Stock, February, 1924. Sucker (in foreground) from Stock shows " Reversion," June, 1925.

FIG. 4.
" Reversion " was equally readily transmitted by inarching Normal with " Reverted " Plants as shown above.

FIG. 5.
"Control" Plant—showing Normal Grafts growing upon Normal Stock.

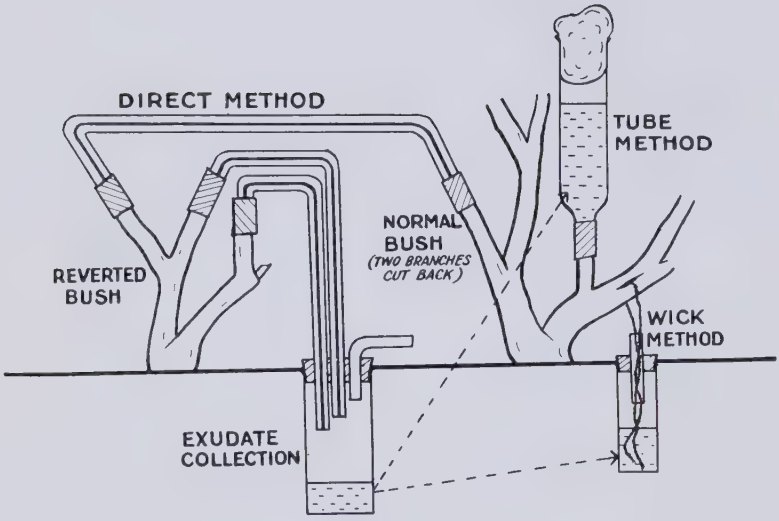


FIG. 6. Diagram showing Methods of Transference of Exudate from Reverted to Normal Bushes.

OBSERVATIONS ON THE PRESENCE OF MITES (*Eriophyes ribis*) UPON BLACK CURRANT BUSHES MANIFESTING REVERSION AND BIG-BUD.

By A. M. MASSEE.

1. Mite Population upon Badly Reverted Bushes Showing Little or or no Big-Bud.

A detailed account is appearing elsewhere of the outbreak of Reversion upon the Variety Trial Plot planted at East Malling in February, 1920. Certain of the young bushes showed all the extreme symptoms of reversion during the first growing season, but they were left in situ, for observation purposes, until December, 1922, when they were grubbed and handed over to the writer for detailed examination. Five bushes were selected for this purpose, three of which, although reverted since the growing season of 1920, had shown no big-bud before the autumn of 1922, the other two having shown one big-bud each in the spring of 1922. Every bud was removed from these bushes for individual examination under a binocular miscroscope. A record was thus obtained of the actual number of buds inhabited by Gall Mites. The result of this examination is summarised in Table I.

Variety.	Degree of Reversion.	No. of Buds on Bush and examined.	No. of apparent big-buds.	No. of Buds containing Mites.	
				big-buds.	Normal Buds.
Black Naples ..	5 E*	488	1	0	0
Prince of Wales	4 E	374	2	1	1
Champion ..	5 E	778	3	3	2
Blacksmith ..	5 E	538	0	0	1
Goliath	4 E	884	12	1	1

Three facts stand out clearly from the Table.

First, although all these young bushes showed extreme symptoms of reversion even in 1920, after three growing seasons, with one exception, very little big-bud was present.

Third, in the case of the Goliath bush, only one of the apparent big-buds showed any signs if mite infestation. The first fact by itself seemed to strengthen the theory elaborated elsewhere in this volume that such bushes were actually

* As detailed elsewhere in this report the numeral represents the number of fifths of the bush affected, and the letter E the extreme stage of the disease.

potential cases of reversion, when planted as cuttings and that the subsequent manifestation of mite attack was merely incidental.

Facts two and three, proving the presence of mites in apparently normal buds and the existence of " big-buds " free from mite infestation called for further investigation.

2. Mites in Buds Apparently Quite Normal.

A number of shoots of French Black were selected from normal and reverted bushes on which no big-buds had been recorded. A microscopic examination was made of each individual bud thereon, with the result shown in Table II.

Table II.

Number of Mites found in Buds appearing Normal.

No. of Shoots examined.	Condition of Shoot.	No. of normal Buds examined.	No. of Shoots with Mite infested Buds.	No. of Buds containing Mites.
68	Reverted	803	19	61
68	Normal	885	8	13

Out of a total of 1,688 apparently normal buds examined, seventy-four contained living gall Mites. Although the majority of these were upon shoots that had manifested the leaf symptoms of reversion, some were upon shoots which up to the time of examination had exhibited no such abnormality.

Freedom from big-bud is not therefore synonymous with freedom from mite infestation, and the French group of currants, for which freedom from Mite has from time to time been claimed, shows this phenomenon as well as the other varieties previously examined.

Freedom from mite infestation cannot therefore be taken for granted from casual inspection alone.

3. Big-Buds apart from the presence of Mite on the Goliath Group.

As already stated a microscopic examination of twelve such buds upon a reverted bush of Goliath revealed the fact that only one had been attacked by mites. A similar case had occurred both on Black Naples and Prince of Wales. It was therefore decided to study this variety more closely in the field.

During the pruning of Goliath bushes in February, 1923, a considerable number of swollen buds were recorded which would generally be diagnosed as big-buds caused by Mite attack. Although very careful examination seemed to show that the scales of these buds were often less tightly packed than on

genuine mite infested big-buds it would certainly be impossible from an ordinary field examination to separate them from typical big-buds, and the number of doubtful cases would be very large.

In order, therefore, to obtain further information, fifty swollen buds of this type were marked on the bushes after pruning had been completed, and were kept under observation. The last examination of these buds was made on April 16th, 1923. Forty-four of the buds had developed normal leaves and flower trusses, and although each bud had been microscopically examined six times up to this stage, in no case were mites found to be migrating. The other six buds failed to develop normally and were found to contain mites.

These spurious " big-buds " appear to be more or less common varietal characteristics chiefly upon varieties of the Goliath group, and under conditions existing at East Malling it would have been a very serious matter if all the shoots showing big-buds on this variety had been automatically pruned off as a sanitary measure. Again, extra precaution is required in diagnosing mite attack upon this group. Indeed, the observations detailed in these notes would suggest that it is necessary to be cautious generally in drawing conclusions based on the presence and absence of mites as manifested by big-buds.

THE GALL MITES OF THE HIMALAYA BERRY AND RASPBERRY.

By A. M. MASSEE.

During the autumn of 1922 a short note appeared in the *Gardeners' Chronicle* entitled " Abnormal Leaves of the Himalaya Berry and Raspberry." Reference was there made to a species of Gall Mite which was found infesting the Himalaya Berry and Raspberry.

Since the life-cycle and habits of the Gall Mite were not understood, and since it was detected on several plants bearing abnormal foliage, it was considered worthy of further investigation.

From 1923 onwards, this species has been studied from time to time, and several facts of importance have been recorded.

Although there appears to be no authentic record proving the presence of this Mite in the British Isles prior to 1922, it was known on the Continent of Europe as far back as 1890. In that year Dr. Nalepa found a small Eriophyid Mite, of dirty white appearance, feeding on the under surface of Raspberry leaves. He described the Mite, and named it *Eriophyes gracilis*. A careful systematic study has definitely established that the mite in question is the same species as that recorded by Nalepa. This species occurring on Raspberry and Himalaya Berry should therefore be known by the name of *Eriophyes gracilis* Nal. 1890.

Habits of the Mite.

The habits of the Gall Mite are very similar on Himalaya Berry and Raspberry. During the latter part of August, or in September, according to the season, the mites migrate from the foliage and go into hibernation. As a rule, they seek shelter under the bud scales, where they remain until the following spring. The colonies usually consist of five or six individuals. In rare instances, especially on Raspberry, larger groups are detected under the bud scales. Sometimes mites are found in the centre of the buds, but this appears to be an exception to the general rule. Again, mites are occasionally found hibernating in cracks or wounds on the stems, and under the scaly bark. Up to the present they have not been detected in the soil.

Although the mites do not appear to be active during the winter months, there is evidence that some of the immature forms continue to develop. Cast skins are frequently found under the bud scales.

During the spring, usually in March or April, the mites become very active, and feed on the bud tissue for a considerable time before migrating to the open.

Before leaving their winter quarters they adapt the curious habit of attaching themselves to the outer surface of the bud scales, by means of their sucker-like disc, which is situated at the anal end of the abdomen. The mites remain attached to the bud scales in this manner for several minutes, moving their bodies rapidly, and waving their legs. These motions are repeated several times, until finally the mites let go their hold, and scatter themselves over the leaves of the plants. They usually fall onto leaves below the bud to which they were previously attached.

In the spring and summer, the mites live and reproduce on the under surface of the leaves, in the flowers, and later on the developing fruits. Here the eggs and immature mites are to be found. The adult females, which are a little longer and of greater breadth than the males, are found in greater numbers. As a matter of fact mature males are rarely found.

The damage caused to the foliage by the feeding of the mites is not very conspicuous, unless the attack is very severe. In such cases the upper surface of the leaf becomes mottled, and of a whitish appearance. This mottled appearance is more pronounced on the leaves of Himalaya Berry than on those of the Raspberry. In extreme cases the mid rib of this leaf becomes constricted. The construction is more noticeable from the under surface of the leaf. As already pointed out, the mites, in all stages, are found in the flowers and developing fruits. When present in large numbers they cause a considerable amount of damage to the fruits of the Himalaya Berry. The fruits of the Raspberry become malformed to a lesser extent. Attacked fruits do not develop normally. The berries ripen off when only half developed, and are usually of a dull reddish-brown colour.

The fruits of the Loganberry and wild Blackberry are also frequently similarly damaged ; but whether a closely allied species of mite is responsible remained to be proved.

Association of Mites with Abnormal Foliage.

The fact that these mites have always been found in greatest numbers on canes showing abnormal foliage, suggested that there might be some correlation between the mites and this manifestation upon the host plants. With this in mind, a small experiment was undertaken at East Malling during 1923, 1924 and 1925, the main object being to explore the possibilities of making direct infections.

Two plants of Himalaya Berry growing out in the open were selected. The plants appeared quite healthy and growing vigorously. They were cut to ground level, and the canes removed to the laboratory. During December, 1923, each bud was examined, with the aid of a binocular microscope, to determine whether mites were present. No mites were found as a result of this examination.

In the spring, as soon as the plants had produced sufficient growth (roughly about six inches), an attempt was made to directly infest them with Gall Mites (*E. gracilis* Nal), from infected canes. These direct transfers proved successful, and, towards the end of the summer, Gall Mites were established on each plant.

Observations were made on the plants during 1924. They grew quite normally and vigorously. The foliage on all the shoots was noted as normal throughout the year. The infections were repeated in the spring of 1925. During the succeeding summer the foliage of two new growths of one plant, and of one shoot of the other, was distinctly abnormal.

The leaves were very much drawn out, they had very coarse serrations, and lacked the large number of the small spines, which are characteristic of the normal leaf. (See Fig. 1).

Throughout 1926 the plants upon the under surface remained abnormal.

It is of interest to note that both plants produced abnormal foliage after direct mite infection, but it cannot be claimed that the mites were the direct or indirect cause of the malformation of the leaves, since the experiment was on so small a scale and without control plants. However, the results seem to justify the repetition of the experiment on a somewhat larger scale.

The Gall Mites are very common on many varieties of Raspberries during the summer months : and as already indicated they are most easily found on plants which have abnormal foliage. The mites have even been detected on very young Raspberry seedlings. In some instances these seedlings have been only two or three weeks old. Many of these seedlings have malformed foliage, and the damage caused has in some cases been so severe that the plants are rendered useless.

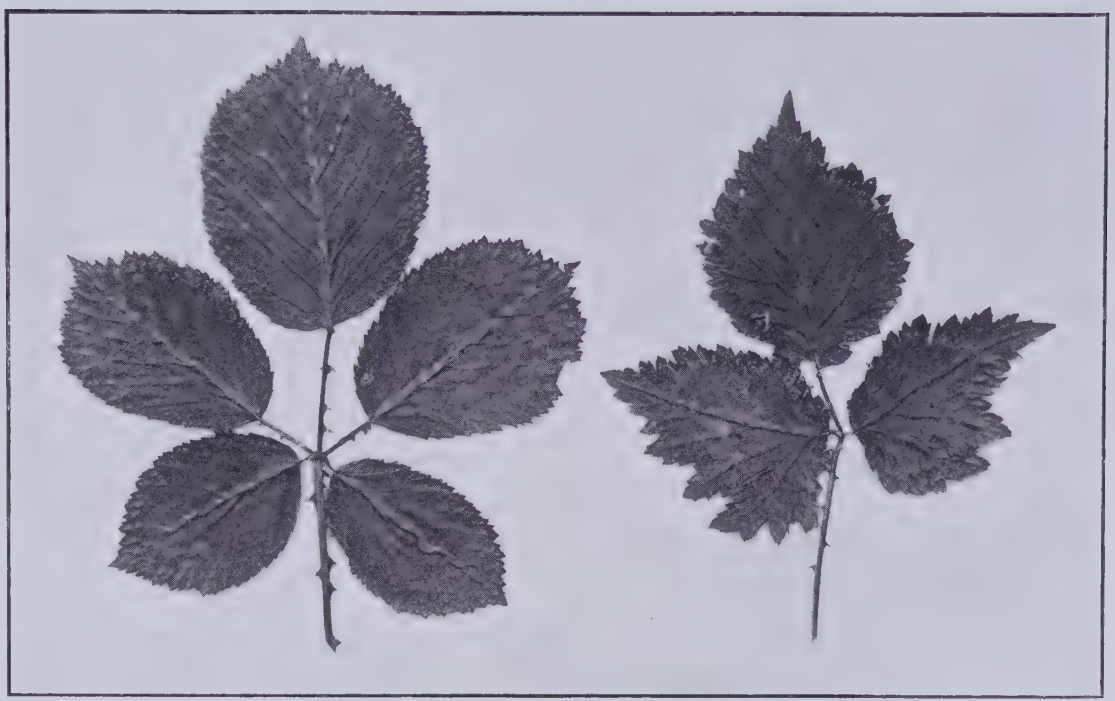


FIG. 1. Normal (left) and abnormal foliage of the Himalaya Berry.

NOTES ON INSECTS AND OTHER PESTS IN 1925.

By A. M. MASSEE.

The following notes are the result of observations made on the Research Station, during visits paid to Growers' plantations and from the letters of enquiry received.

1. Red Spiders (*Oligonychus ulmi* C. L. Koch, 1835).*

The common Red Spider was one of the most prevalent pests of the district. In 1924 it was reported to be on the increase in many localities and several growers made enquiries about its control, but in 1925 it became still more prevalent, and many growers for the first time realised the damage that might result. Seventeen enquiries were received as to the control of these mites.

At East Malling, the pest mainly confined its activities to the young apple and plum trees, though pears, hops and many other plants are commonly infested by it.

On Apples.

The leaves were most frequently damaged—often to a considerable extent—though in some cases of severe attack even developing fruits and young growth were partially checked. A badly infested tree can readily be detected by the peculiar appearance of the leaves, which change from a fresh green to a dull silvery colour. The mites usually live and feed in small webs which are attached to the undersides of the leaves, but when very abundant they may be detected on both surfaces of the leaves and on the stems and trunks. This pest seems to occur in the greatest numbers on apple during the latter part of June and July, when the tree should be making its maximum growth.

On Plums.

Both young trees growing in the Nursery and established trees in the plantations were severely affected by Red Spider attack. The growth was checked and the leaves dried up prematurely. Some varieties appeared to be more susceptible than others.

On Pears.

Generally speaking, pears did not suffer to the same extent as the foregoing fruits, though two plantations in the district were severely infested.

* The names *Paratetrarychus pilosus* Zacher and *Tetranychus telarius* L. have been used by recent authors for this species; but the name referred to in the text is considered correct.

On Hops (Tetranychus telarius L.).*

Although small numbers of Red Spider were present on most hop hills at the Research Station, the damage was comparatively slight. In other localities however, hops suffered severely, the number of mites increasing very rapidly during August. Early in August the Red Spiders migrate from the bines and establish themselves on the cones. Once in the cones they are not easily dislodged by spraying, without causing damage. The cones become discoloured by the attack. In September the Red Spiders were observed to be migrating from the hills to the soil, and in one heavily infested garden, when the clods of earth were turned over, masses of these mites were revealed which gave the soil quite a reddish colour. They were also found sheltering in the cracks in the hop poles.

On fruit trees, as a rule, the Red Spiders pass the winter in the egg stages. The eggs are mainly deposited on the trunks, in cracks or wounds, and around the bases of spurs.

Control Measures.

During the winter of 1924-25, some of the apple plantations at the Research Station were sprayed with a proprietary tar distillate wash. The majority of the trees so sprayed were, at the time, noted as being covered with thousands of Red Spider eggs. In the following spring, these hatched in large quantities despite the spraying.

A series of definite experiments confirmed this observation that the proprietary tar distillate was ineffective against these eggs.

In the spring these same plots were sprayed with a combined fungicidal and insecticidal wash, just before blossom opened, and again ten days later. One plot received Bordeaux Mixture (formula 8.8.100), and 4 lbs. of Arsenate of Lead, and 6 ozs. of Nicotine. Another received Lime Sulphur (1 in 30), together with similar quantities of Arsenate and Nicotine. The second application of Lime Sulphur, post blossom, was at the reduced strength of 1 in 60. Whilst a general survey showed that on this latter plot the Red Spiders were controlled to a very large extent, the plot sprayed with Bordeaux Mixture remained heavily infested. On another plantation of Apples, Liver of Sulphur (3 lbs.), and Soft Soap (5 lbs. per 100 galls. water) was used after blossoming. This treatment was of considerable value in controlling the pest. On Plums, an attempt was made to eradicate the pest by spraying with 8 gallons of flour paste to 100 galls. water. Though two or three sprayings were given, the attack was not sufficiently checked to allow of the trees growing away from it.

On Pears, all control measures tried were found inadequate.

* The Red Spider on Hops is known as *Tetranychus althææ* V. Han. by some authorities.

2. Apple Sawfly (*Hoplocampa testudinea* Klug).

Apple Sawfly was troublesome in some districts. In one old and somewhat neglected plantation fully two thirds of the crop was destroyed by the pest. It is on the increase in the young plantations at this Research Station, the varieties most heavily attacked being James Grieve and Worcester Pearmain.

3. The Clay Coloured Weevil (*Otiorrhynchus picipes* F.).

The Clay-coloured Weevil appeared early in the spring on currant bushes and newly grafted apple stocks.

As mentioned in the Annual Report for 1924 this Weevil eats through the petiole of the newly-formed leaves of the currant, causing them to wilt and finally drop off. Young bushes appear to be more frequently attacked, and are often completely defoliated.

Damage of this kind by weevil was recorded from several sources during the spring.

At East Malling, newly grafted apple trees were damaged as a result of weevil attack. The injury to some grafts was considerable. The leaf buds are eaten by the weevils as soon as they open, causing the grafts to die out.

Early in the year the Clay-coloured Weevil was observed feeding on the bark of young apple trees. The damage was not serious, but probably would have been, but for the timely application of an Arsenic Spray. This wash completely checked the weevils on both currants and apples. Unfortunately, it was not possible to trace whether the arsenical spray killed the weevils, or only acted as a deterrent.

4. The Hop Frog Hopper (*Euacanthus interruptus* L.).

This bug has been prevalent in some hop gardens during May, June and July. It was first reported in a hop garden near Maidstone, about the middle of May. At that period the bugs were in the immature stage. They were feeding on both surfaces of the leaves, and, in the early part of the season, were generally found at the base of the bines. Later in the season, they worked their way up the shoots and fed on the new succulent growths.

These bugs are rather difficult to find and still more difficult to catch, as they hop readily, and fall to the ground as soon as the bines are disturbed. Towards the middle of July they attain the adult stage. They are then more easily detected, the punctured leaves are very conspicuous by this time.

The Leaf Hoppers have sucking mouthparts.

Continued spraying with a Nicotine Soap solution proved of very little value against the leaf hoppers ; it was not even effective when applied at a greater strength than is generally recommended for Hop-Damson Aphis control. The

failure of the Nicotine spray was probably due to the quick jumping habits of the Leaf Hoppers.

Finally, a somewhat primitive method of control, that of jarring the bugs off the bines on to tarred sacking, was tried. This treatment proved quite successful, but it could not be considered entirely satisfactory in view of the time and labour required. The jarring process had to be repeated at each hill, before the Leaf Hoppers were sufficiently reduced in numbers to permit the hops to grow away from them.

These Leaf Hoppers were noted in the Hop Gardens at the Research Station during the summer months, but only in small numbers, and they did not materially affect the growth of the hops

N.B.—A full list of Published Reports to date can be obtained on application.